Bank Opacity and Safe Asset Moneyness[*]

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Abstract

A bank is more effective as a supplier of money-like safe assets when 1) its return on equity (ROE) is relatively lower, and 2) it is relatively more opaque about its balance sheet. A model is presented to support this, emphasizing that safe asset investors focus on the left tail of the bank asset value distribution, which ultimately determines its debt's moneyness. Empirical tests on dealer banks and money market mutual funds' (MMFs) funding relationships confirm that higher ROE leads to MMF withdrawal due to lower moneyness of safe assets. Bank opacity mitigates the strength of this relationship, making it optimal for the banking system to maintain a certain level of opacity.

Keywords: safe asset, private money, bank opacity, safe asset moneyness, bank profitability

JEL Codes: E44, E61, G01, G18

1   Introduction

A financial asset is "money-like" or has high "moneyness" if it is safe and liquid, which means it is traded at par value in transactions with no questions asked.[1] The banking system is a vital producer of money-like safe assets (Gorton 2017). In this paper, I ask when a bank is more effective as a supplier of privately produced money-like safe assets.[2] I find that a bank produces a safe asset that is more money-like when it is relatively *less profitable* and when it is relatively *more opaque* about its balance sheet.

Safe asset moneyness is time-varying and depends on safe asset holders' assessment of the backing collateral.[3] Compared to moneyness of public safe assets like the Treasuries, moneyness of privately produced safe assets is not foolproof, as we saw in the Global Financial Crisis. Investors ran on repurchase agreement issued by investment banks when investors started doubting the value of mortgage-backed securities that were backing many of the repo.

As privately produced money-like safe assets usually have very short maturity and are collateralized by complex securities, most investors do not have the luxury of time or ability to do complete due diligence on the assets every time they agree to hold them. Billions of dollars of repo, for example, are rolled over every day without much of a second thought. In fact, Gorton and Pennacchi (1990) and Dang, Gorton, and Holmström (2012) show money-like safe assets are purposefully designed to be information-insensitive so that investors have little incentive to produce private information about them. Banks are "opaque" and intentionally make it hard for safe asset holders to obtain detailed information about the asset side of their balance sheets (Dang et al. 2017).

In the setting where the banking system is trying to be opaque, this paper shows that a bank's profitability, as measured by its return on equity (ROE),[4] is a significant piece of public information that predicts the moneyness of the safe assets issued by that bank. This paper also demonstrates that the predictiveness of a bank's ROE depends on the bank's level of opacity about its balance sheet.

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[1]The word "moneyness" in this paper does not refer to the value of an option. It refers to how safe and liquid a financial asset is.

[2]Privately produced money-like safe assets such as repo and commercial paper are a form of debt financing to banks. Therefore, they are on the right-hand side of banks' balance sheets. However, for investors that hold them, these assets are on the left-hand side of their balance sheets. Throughout this paper, I call a money-like safe asset a *debt* when I am looking at it from the perspective of banks or an asset when I am looking at it from the perspective of investors. An investor in money-like safe assets can equivalently be called a *debt holder* or a *safe asset investor*.

[3]Papers like Nagel (2016) and Krishnamurthy and Li (2021) show how proxies for safe asset moneyness have been fluctuating for the last hundred years.

[4]A company's return on equity is defined as its net income divided by its shareholders' equity.

Using a bank's ROE as a measure of risk for the bank is not entirely novel in the literature. However, the evidence has been inconclusive when it comes to showing whether a higher ROE means a higher or lower risk for the bank. On one hand, there are papers like Meiselman, Nagel, and Purnanandam (2023) that show a higher ROE of a bank exposes the bank to a higher systemic tail risk during the crisis. On the other hand, there are papers like Chen et al. (2022) that argue a higher ROE results in an inflow of uninsured deposit in the retail banking space, suggesting that a higher ROE of a bank signals lower risk to retail depositors.

This paper contributes to this debate by looking at the *wholesale banking sector.* Compared to the retail banking sector, the wholesale banking sector is populated by more informed depositors[5] like money market mutual funds or pension funds, and it is equally if not more important short-term funding source for financial intermediaries (Gertler, Kiyotaki, and Prestipino 2016). In this setting, I show that a higher bank ROE results in wholesale depositors *withdrawing* from the bank. I explain this phenomenon by demonstrating that a higher ROE bank tends to issue short-term debt that are considered less safe and less liquid, which translates to a lower moneyness for the debt issued by such bank.

In the first part of the paper, I build a three-period model of a bank that issues money-like safe assets called deposit to finance itself and a household that holds them not only to transfer its wealth intertemporally but also to use them as money. The model shows that higher ROE of a bank lowers the moneyness of the deposit and thus increases the likelihood that the household withdraws from that bank.

The intuition for this result stems from the fact that the household cares almost entirely about the left tail of the bank asset value distribution. In the model's setting, more profitable bank is not necessarily good news to the household who is a debt holder. Even if the bank is highly profitable, the upside for the household is limited to the interest rate promised by the bank ex-ante. On the other hand, the downside involves a higher likelihood of complete insolvency of the bank, leaving the household unable to recover at least a portion of their money. A higher ROE of a bank signals that the bank is more likely to be engaging in riskier investment activities with a higher volatility of returns. The household realizes that they are more exposed to the left tail of the bank asset value distribution, which makes a higher proportion of the deposit risky. This lowers the deposit's moneyness and ultimately leads to the household's withdrawal of its deposit from the bank as the deposit's role as money has diminished.

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[5]Throughout this paper, I consider institutional investors buying repo issued by a dealer bank, for example, depositing at the bank.

To derive this result, the model has the following three key ingredients. First, the household gets direct utility from holding the deposit, but only from the proportion of the deposit holding that is riskless and thus money-like. This feature of the model captures the spirit of papers like Gorton and Pennacchi (1990), Stein (2012), and Dang, Gorton, and Holmström (2012) where only the information-insensitive assets serve the role of money as parties involved in transactions using such assets are immune from adverse selection. Second, the household's assessment of the moneyness of the deposit is a crucial determinant of its consumption-saving choice.

Third, to capture the idea that the household only has limited information about the bank to assess the moneyness of the deposit, the model features bank opacity. The household needs to determine how risky the bank's asset portfolio is in order to determine the moneyness of the deposit it holds. However, as the bank is opaque, the household only uses information that the bank publicly announces to determine the moneyness of the deposit issued by the bank. In particular, the household extracts information about the bank asset's riskiness only from the bank's ROE.

I also conduct a welfare analysis and show that the bank being opaque is not only privately optimal for the bank but also socially optimal. Opacity is privately optimal for the bank because, as a risk-neutral investor, investing in riskier assets with higher expected returns is more desirable for maximizing its own net worth. Therefore, when making its asset allocation decision, the bank only cares about maximizing its net worth by increasing the risky asset holding as much as possible. In particular, the bank does not consider its asset allocation choice's effect on the overall financial services that the deposit provides to the household.

In addition, the bank being opaque is socially optimal. The sensitivity of the deposit's moneyness to changes in bank profitability is lower when the bank is opaque than when it is transparent. This is because a higher opacity means bank ROE is less informative about the riskiness of the bank's asset portfolio. The household can allow itself to hold on to more money-like safe assets without having to worry about the assets losing moneyness. Bank opacity resolves the inefficiency caused by the household prematurely panicking and running on the bank in response to a slight uptick in the bank asset portfolio's riskiness. It prevents a financial crisis that is instigated by a mere bank liquidity event.

In the second part of the paper, I test four predictions that are borne out of the model by examining funding relationships between dealer banks and money market mutual funds (MMFs). Dealer banks and MMFs are, respectively, one of the most active issuers and holders of privately produced money-like safe assets.

First, I study the relationship between dealer banks' ROE and MMFs' investment de-

cisions by showing that a one percentage point increase in a dealer bank's ROE results in a 2.48% decrease in an MMF's holding of money-like safe assets issued by that dealer bank. The economic significance of this empirical result is accentuated when we look at a dealer bank ROE's effect on the investment decisions of MMFs during a crisis period as suggested by Meiselman, Nagel, and Purnanandam (2023). I show that the identified effect was especially strong in the second quarter of 2020 when the financial market was in significant turmoil due to the COVID-19 crisis. In the second quarter of 2020, a one percentage point increase in a dealer bank's ROE resulted in a 42% decrease in an MMF's holding of privately produced money-like safe assets issued by that dealer bank.[6]

Second, I provide an explanation for this empirical pattern by showing that a safe asset issued by a bank with a higher ROE is associated with lower moneyness. Moneyness is proxied by a convenience yield, which is a yield spread between privately produced safe assets and public safe assets. If a bank produces a safe asset that is more money-like, the bank is compensated by being able to pay a lower interest rate, or equivalently, by earning a higher convenience yield. Using this yield spread as a proxy for safe asset moneyness, I show that a one percentage point increase in a dealer bank's ROE results in a 0.49 basis point decrease in the convenience yield of privately produced money-like safe assets issued by that dealer bank. Again, I show that this effect of bank ROE on the safe asset moneyness was much stronger during the COVID-19 crisis period.

Third, I test the model's implication about bank opacity. Using the empirical proxy for bank opacity, I show that when a bank is more opaque, MMFs' investment decisions become less responsive to changes in the bank's ROE. I also show that this is because safe asset moneyness becomes less responsive to changes in the bank's ROE when the bank is more opaque.

Fourth, I demonstrate that a more opaque bank is capable of holding riskier assets on its balance sheet without compromising the moneyness of its short-term debt.

The results in this paper provide insights for policymakers and regulators whose goal is to maintain a sound financial system and facilitate the financial intermediation function of the banking system in the following ways. First, banks' ability to produce money-like safe assets and investors' perception of safe asset moneyness pass through banks' balance sheets, and ultimately affects the real economy. When banks can issue safe assets that are perceived to have higher moneyness, safe asset holders compensate them by offering to lend to them at a lower interest rate. A lower debt financing cost strengthens banks' balance sheets, which ultimately bolsters their ability to lend to the real economy.

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[6]I show that the main negative relationship between dealer banks' ROE and MMFs' investment decision still holds without the COVID-19 crisis period.

Furthermore, the research question posed in this paper is important, especially if one thinks of a financial crisis as an event when investors run on privately produced money-like safe assets that lost their moneyness, like when investors ran on repo in 2008 (Gorton and Metrick 2012; Gorton 2018; Dang, Gorton, and Holmström 2020). Policymakers can look at a simple and publicly available metric like the bank ROE to assess investors' perception of safe asset moneyness and the potential for a bank run without having to conduct expensive and time-consuming bank audits.

Literature Review This paper is related to the literature on money-like safe asset production. Diamond and Dybvig (1983), Gorton and Pennacchi (1990), and Holmström and Tirole (1998) were some of the first papers that thought about a bank's role as a transformer of illiquid long-term assets into liquid money-like safe assets. Recent theoretical papers like Dang, Gorton, and Holmström (2012) build on this to argue that short-term debt, whose investors do not have to worry about adverse selection, serve the role of money. In their words, these kinds of assets are information-insensitive. Using this idea of information-insensitivity of money-like assets, Dang et al. (2017) argue that banks are optimally opaque to disincentivize investors from producing private information about the assets, which will keep them from turning information-sensitive. Papers like Caballero (2006), Caballero, Farhi, and Gourinchas (2016, 2017), and Caballero and Farhi (2017) theoretically study the reason for safe asset shortages and the need for private production of safe assets.[7]

There is a vast line of empirical literature that studies various types of money-like safe assets. Krishnamurthy and Vissing-Jorgensen (2012, 2015) show how private safe asset production is conducted in response to a shortage in public safe asset such as Treasuries. Sunderam (2014) studies the role of the commercial paper market as another important producer of private money-like safe assets. Papers like He and Song (2022) and Ross (2022) also study alternative sources of privately produced money-like safe assets.[8] Huber (2023) builds a structural model of the triparty repo market and estimates it using the same data that I use in this paper. As mentioned before, Meiselman, Nagel, and Purnanandam (2023) and Chen et al. (2022) show how bank ROE can be interpreted as a measure of risk and how it depends on bank opacity.

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[7]In addition, papers like Gennaioli, Shleifer, and Vishny (2013), Plantin (2014), Farhi and Tirole (2020), Brunnermeier and Sannikov (2014), He and Krishnamurthy (2013), and Moreira and Savov (2017) study roles that financial intermediaries–especially shadow banks that were outside the purview of regulators–played in the financial crisis.

[8]Papers like Greenwood, Hanson, and Stein (2015), Nagel (2016), Kacperczyk, Pérignon, and Vuillemey (2021), and He, Nagel, and Song (2022) also contribute to this literature.

2 Model

In this section, I build a three-period model of a *bank* that issues money-like safe assets called deposit to finance itself and a *household* that uses the deposit not only to transfer its wealth intertemporally but also to use it as money.

I start the section by showing the household's problem taking as exogenously given the deposit's moneyness. I endogenize moneyness by first presenting the benchmark model of a perfectly transparent bank. Then I characterize bank opacity by showing how the household extracts information from limited information about the opaque bank and evaluates the moneyness of the safe asset that the bank issues. Finally, I conduct a welfare analysis and investigate what the implication of bank opacity is for the overall welfare of the economy.

2.1 Model Overview

The economy lasts for three periods. Time is indexed by $t = 0, 1, 2$. The economy is populated by a representative bank and a representative household. There are three states of the world: high state denoted H, medium state denoted M, and low state denoted L, which happen with probabilities p_H, p_M, and p_L, respectively. The state of the world determines the bank's return on its risky asset denoted z, and it is the only uncertainty in the model.

The bank is funded by its initial endowment of net worth n_0 and deposit m_0. The household is the lender that holds the deposit m_0 with the bank. The bank's objective is to choose to invest in either a risky asset l or a safe asset s at date $t = 0$ to maximize its date $t = 2$ net worth n_2, which will be consumed by the bank owner. The bank has to take into account the maturity mismatch problem when making its asset allocation decision at date $t = 0$ as the assets pay off at date $t = 2$ while the deposit matures at date $t = 1$. The household can decide to withdraw the deposit at date $t = 1$, which necessitates a premature liquidation of the bank's asset that is costly.

The household is risk neutral and is born at date $t = 0$ with an endowment of deposit m_0 that it holds in the bank. There are two cases that I am going to consider: when the bank is *transparent* and when the bank is *opaque*. When the bank is transparent, the household directly knows the bank's choice of the risky asset l and the safe asset s as well as the return shock z to the risky asset and uses this information to determine the deposit's moneyness θ. On the other hand when the bank is opaque, the bank announces its ROE at the beginning of date $t = 1$, and it is the only information that the household has about the bank. Therefore, the household needs to indirectly infer how much of the

bank's resources are invested in the risky asset to determine deposit's moneyness θ.

The model has a sequential structure. The bank asset allocation decision l and s made at date $t = 0$ determines deposit moneyness θ. At date $t = 1$, given its assessment of the deposit's moneyness, the household makes a consumption-saving decision. The decision in turn determines how much of the assets the bank needs to liquidate in order to honor the household's withdrawal request. The timeline of the model for cases when the bank is transparent and opaque is summarized in Figure 1.

I present the model in a backward inductive way. I first start from the end of date $t = 1$ and present the household's problem assuming the deposit's moneyness θ is exogenously given. Then I move to the start of date $t = 1$ and endogenize θ by presenting the household's inference problem of determining the deposit's moneyness from the bank's announcement of its asset allocation decision and z (in the case of transparent bank) or its ROE (in the case of the opaque bank). Finally, I come back to date $t = 0$ and present the bank's asset allocation problem of choosing l and s.

2.2 Household's Problem Given Deposit Moneyness θ

I first present the household's problem, taking as given the deposit's moneyness θ. The risk-neutral household is born at date $t = 0$ with an endowment of a one-period deposit m_0 that it holds in the bank. The initial deposit holding m_0 matures at date $t = 1$ with the deposit rate of r. To focus my analysis on deposit moneyness, I assume the deposit rate r is fixed over time. In Appendix F, I present an extension of the model where the deposit rate changes over time.

The bank-issued deposit serves two roles in the economy. Just as when we use checking accounts to not only save our money for future use but also pay for our lunch in a restaurant, the deposit provides a way for the household to transfer wealth intertemporally and also serves the role of privately produced money.
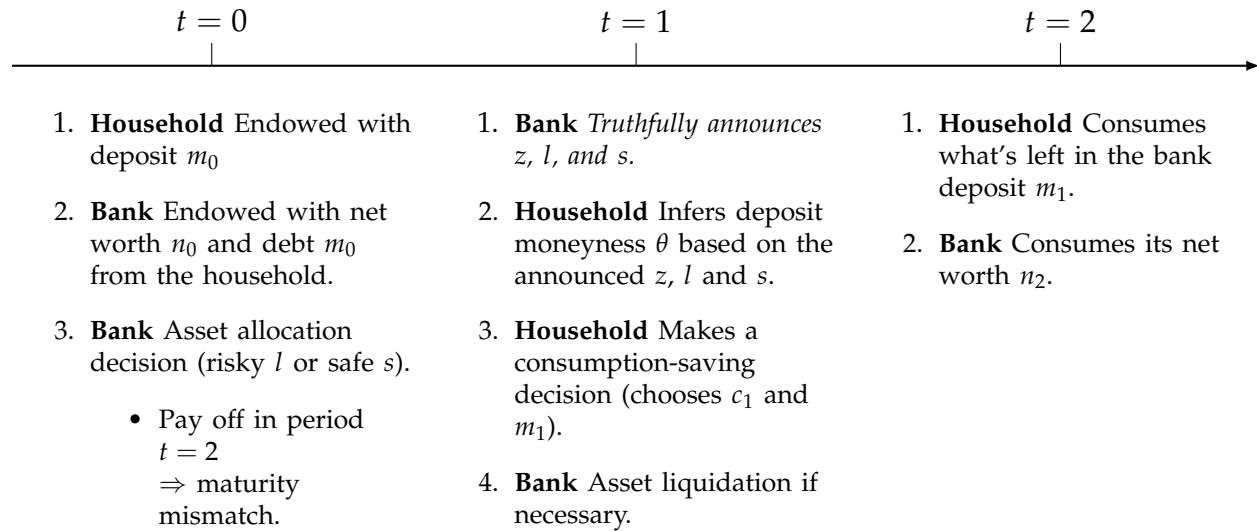
Consistent with the literature on private money, I make the following assumption about the moneyness of the deposit:

Assumption 1. [Deposit moneyness] *Only the proportion of the deposit that is perceived to be riskless serves the role of money.*

This assumption captures the spirit of papers like Gorton and Pennacchi (1990), Stein (2012), Dang, Gorton, and Holmström (2012), and Nagel (2016) where only information-insensitive assets work well as private forms of money. Holders of information-insensitive assets have no incentive to produce private information about the collateral that is backing the assets as they are not worried about adverse selection. They do not fear that the

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Figure 1: Model Timeline

Transparent Bank

$t = 0$	$t = 1$	$t = 2$

1. **Household** Endowed with deposit m_0

2. **Bank** Endowed with net worth n_0 and debt m_0 from the household.

3. **Bank** Asset allocation decision (risky l or safe s).
   - Pay off in period $t = 2$ $\Rightarrow$ maturity mismatch.

1. **Bank** *Truthfully announces z, l, and s.*

2. **Household** Infers deposit moneyness θ based on the announced z, l and s.

3. **Household** Makes a consumption-saving decision (chooses c_1 and m_1).

4. **Bank** Asset liquidation if necessary.

1. **Household** Consumes what's left in the bank deposit m_1.

2. **Bank** Consumes its net worth n_2.

Opaque Bank

$t = 0$	$t = 1$	$t = 2$

1. **Household** Endowed with deposit m_0

2. **Bank** Endowed with net worth n_0 and debt m_0 from the household.

3. **Bank** Asset allocation decision (risky l or safe s).
   - Pay off in period $t = 2$ $\Rightarrow$ maturity mismatch.

1. **Bank**
   - *Privately observes z.*
   - *Truthfully announces marked-to-market ROE.*

2. **Household** Infers deposit moneyness θ based on the announced ROE.
   - Opaque bank $\Rightarrow$ does not observe l, s, or realized z.

3. **Household** Makes a consumption-saving decision (chooses c_1 and m_1).

4. **Bank** Asset liquidation if necessary.

1. **Household** Consumes what's left in the bank deposit m_1.

2. **Bank** Consumes its net worth n_2.

Notes: Difference between the two timelines comes at the beginning of date $t = 1$ (in italics) where the information set that the household has to makes its consumption-saving decision differ.

asset issuers are hiding information about the assets that might potentially make at least a portion of them not be able to be paid back, making the assets risky. Agents involved in transactions using information-insensitive assets have little doubt that these assets are valued at par, which makes them an effective medium of exchange.

The household's problem presented below shows how I embed Assumption 1 in the model. I employ a variant of money-in-utility function to tractably embed the idea of the deposit serving the role of private money.[9] The household's problem is to make a consumption-saving decision at date $t = 1$ in order to maximize its expected utility subject to budget constraints for each date:

$$\max_{c_1, c_2} \mathbb{E}_1[c_1 + \beta c_2 + \alpha \theta m_1]$$

$$\text{such that } c_1 = \underbrace{(1+r)m_0 - m_1}_{\text{withdrawal in period } t = 1}$$

$$c_2 = (1+r)m_1$$

$$m_0 \text{ given}$$

where α is the parameter that controls the relative utility of money holding and β is the time discount factor.

$\theta \in [0, 1]$ captures the spirit of Assumption 1 and denotes the proportion of the deposits that are perceived to be riskless by the household, the construction of which I describe in detail in the following section. Per Assumption 1, only the θ proportion of the deposit serves the role of money, which in the context of a money-in-utility environment means only the θ proportion of the deposit gives the household a direct utility. Throughout this paper, I call θ the deposit's moneyness. A higher θ means a higher proportion of the deposit is perceived to be riskless and thus serve the role of money, which means the deposit has a higher moneyness. θ is determined endogenously at date $t = 1$ prior to the household's making the consumption-saving decision.

As the household is risk-neutral, the solution to its problem is at the corner. The household chooses whether to withdraw everything and consume entirely at date $t = 1$ or to withdraw nothing and consume entirely at date $t = 2$. The household's withdrawal decision depends entirely on how θ compares to a threshold denoted θ^*, which is a function of model primitives.

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[9]This money-in-utility function formulation for modeling liquidity demand is widely used in the literature starting from Sidrauski (1967).

Proposition 1. [Solution to the household's problem] *If deposit moneyness is low; i.e.*

$$\theta < \theta^* \equiv \frac{1 - \beta(1 + r)}{\alpha}$$

the household withdraws everything and consumes at date $t = 1$; that is, $c_1 = (1 + r)m_0$, and $c_2 = 0$. If deposit moneyness is high; i.e. $\theta > \theta^*$, the household withdraws nothing and consumes at date $t = 2$; that is, $c_1 = 0$, and $c_2 = (1 + r)^2 m_0$. If $\theta = \theta^*$, the household is indifferent.

Proof. All proofs are in the Appendix. □

The household's decision rule is simple. If the moneyness of the deposit is high enough that the deposit's additional use as money is more than enough to compensate for the delay in consumption, the household keeps the deposit in the bank. Otherwise, the household withdraws everything and consumes at date $t = 1$ without holding any money.

Discount factor β, deposit rate r, and money demand shifter α together determine the threshold θ^* for the household's decision to withdraw or not at date $t = 1$. If the household is more patient (β high), the withdrawal threshold becomes lower. This means the household is willing to delay consumption even if the deposit's additional use as money is lower. If the household values the deposit's role as money more (α high), the withdrawal threshold becomes lower. A higher α means the marginal utility from money holding is higher even if the quantity of money holding is lower due to a lower θ. This means the household is willing to hold the deposit at a lower θ value. Finally, if the deposit rate is higher (r high), the withdrawal threshold also becomes lower. Even if the deposit's role as money is lower with a lower θ, the amount of consumption goods that the household can additionally earn by holding the deposit for one more period is higher with a higher r. This incentivizes the household to hold the deposit at a lower θ value.

2.3 Transparent Bank

I first present the benchmark case when the bank is transparent. When the bank is transparent, the household directly knows the bank's choice of the risky asset l and the safe asset s as well as the realized shock $z \in \{z_L, z_M, z_H\}$ at the beginning of date $t = 1$.

2.3.1 Moneyness θ definition

In order to define the deposit's moneyness θ, I make the following parametric assumption about the model parameters.

Assumption 2. [Bank insolvency] *Model parameters are such that the bank is insolvent only in the low L state.*

Using Assumptions 1 and 2, the deposit's moneyness θ is formally defined as follows.

Definition 1. [Definition of θ for a transparent bank] θ is defined to be the proportion of deposit m_0 that the household thinks is risky:

$$\theta \equiv 1 + \underbrace{\frac{p_L}{} \overbrace{\frac{[\overbrace{z_L l + r^s s - r m_0}^{\text{loss at date } t = 1} + n_0]}{m_0}}^{\text{(1) amount of deposit lost in state } L}}_{\text{(2) proportion of deposit lost in state } L} \tag{1}$$

By Assumption 2, the household knows that if the low state is realized, the profit would be so negative that it wipes out the bank's equity n_0 and makes at least a proportion of the deposit unable to be paid back. Term (1) in Equation (1) shows how much deposit is lost in the low state, as it is assumed by Assumption 2 that $|z_L l + r^s s - r m_0| > n_0$. I normalize the loss by the household's deposit holding amount m_0 to make the absolute value of the fraction denote the *risky* proportion of the deposit.[10] I add 1 to the fraction to take the complement of the fraction and calculate the risk*less* proportion of the deposit that serves the role of money to be consistent with Assumption 1.

2.3.2 Transparent bank's problem

I move to date $t = 0$ and present the bank's problem. The bank is born at date $t = 0$ with an initial endowment of equity n_0 and debt financing in the form of the one-period deposit m_0 that the household provides. Funded by the equity and the deposit, the bank makes an asset allocation decision at date $t = 0$ between risky asset holding l and safe asset holding s that pay off at date $t = 2$. There is a maturity mismatch between the bank's asset that pays off at date $t = 2$ and the deposit that matures at date $t = 1$. If the household decides not to roll over the deposit from date $t = 1$ to date $t = 2$, the bank has to prematurely liquidate its asset at a cost. The safe asset s gets a constant return of r^s. The risky asset l is subject to an exogenous return shock z. The bank's objective is to choose its asset allocation between the risky asset l and the safe asset s in order to maximize its expected final date $t = 2$ net worth.

At date $t = 1$, the household withdraws $\mathcal{W} \equiv (1 + r)m_0 - m_1$ amount of the deposit from the bank. The bank pays out the withdrawal by liquidating its risky and safe assets.

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[10]Since term (1) is negative, the absolute value of the fraction term (2) denotes the risky proportion.

When the bank prematurely liquidates its assets at date $t = 1$, it gives up the returns z and r^s as they are only realized at date $t = 2$. Furthermore, liquidating the risky asset incurs an additional cost. If the risky asset is liquidated prior to date $t = 2$, the bank not only gives up the return to the risky asset z but also has to pay a marginal liquidation cost δ for every unit of risky asset it liquidates. This always makes it optimal for the bank to liquidate the safe asset first. However, if the withdrawal amount $\mathcal{W}$ is so big that the liquidation of the safe asset is not enough to satisfy the redemption demand from the household, the bank liquidates the risky asset as well.

Going back to the solution to the household's problem presented as Proposition 1, we saw that the withdrawal decision of the household at date $t = 1$ is binary. When the deposit moneyness is lower than the threshold θ^*, the household withdraws all of its deposit, which means $\mathcal{W} = (1 + r)m_0$. Otherwise, it does not withdraw at all, which means $\mathcal{W} = 0$. The following corollary to Proposition 1 shows the implications of this solution to the household's problem to the bank.

Corollary 1. *There exists threshold values θ^* for θ where*

$$\theta^* \equiv \frac{1 - \beta(1 + r)}{\alpha}$$

- *The bank does not liquidate any asset at date $t = 1$ if $\theta \geq \theta^*$*

- *The bank liquidates only the safe asset at date $t = 1$ if $\theta < \theta^*$ and $\mathcal{W} < s$*

- *The bank liquidates both the safe and the risky loan at date $t = 1$ if $\theta < \theta^*$ and $\mathcal{W} > s$*

Corollary 1 lets me write the bank's problem as follows.[11] The bank's problem is to choose its asset portfolio to maximize its expected date $t = 2$ net worth n_2 as follows:

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[11]When the deposit maintains a certain level of moneyness, it is information-insensitive, and the household does not have an incentive to produce private information about the bank's asset and withdraw. This is the first case in Corollary 1. If the deposit's moneyness falls below the threshold θ^*, which is in turn completely determined by the household's primitives, the deposit turns information-sensitive, and the household withdraws from the bank.

$$\max_{l,s} \mathbb{E}_0[n_2]$$

$$\text{such that } n_2 = \begin{cases} (1+z)l + (1+r^s)s - rm_0 - (1+r)m_1 & \text{if } \mathbb{E}[\theta] \geq \theta^* \text{ and } \mathcal{W} = 0 \\ (1+z)l + (1+r^s)(s - \mathcal{W}) & \text{if } \mathbb{E}[\theta] \leq \theta^* \text{ and } \mathcal{W} < s \\ (1+z)(l - [\mathcal{W} - s]) - \delta(\mathcal{W} - s) & \text{if } \mathbb{E}[\theta] \leq \theta^* \text{ and } \mathcal{W} > s \end{cases}$$

$$l + s = n_0 + m_0$$

$$\mathcal{W} = \begin{cases} 0 & \text{if } \theta \geq \theta^* \\ (1+r)m_0 & \text{if } \theta \leq \theta^* \end{cases}$$

$$\theta^* \equiv \frac{1 - \beta(1+r)}{\gamma}$$

The first constraint shows what the date $t = 2$ net worth is going to be for each case of deposit moneyness and the bank's need for asset liquidation. Since the bank is solving its problem at date $t = 0$ before θ is determined, it compares the expected θ to the threshold θ^*. There is no withdrawal when $\theta > \theta^*$. In this case, the bank's net worth at date $t = 2$ is equal to the return on the asset less the interest payout rm_0 at date $t = 1$ on the deposit, and the redemption of the deposit $(1 + r)m_1$ in the final period.

If there is a withdrawal because $\theta < \theta^*$, but the bank's safe asset holding is enough to honor the withdrawal; i.e. if $\mathcal{W} = (1 + r)m_0 < s$, the bank earns r^s for the remaining $s - \mathcal{W}$ units of the safe asset holding while earning the entire $(1 + z)l$ for the risky asset holding at date $t = 2$ as no risky asset had to be liquidated.

Finally, the withdrawal amount $\mathcal{W}$ can be so big that the safe asset holding alone is not enough to honor the withdrawal. If this is the case, the bank liquidates the entire safe asset holding s, which means the bank earns nothing from the safe asset. Additionally, the bank also has to liquidate $\mathcal{W} - s$ units of the risky asset, which means the bank has to pay $\delta(\mathcal{W} - s)$ units in terms of liquidation cost. When this happens, the bank is left with earning the return z on $l - (\mathcal{W} - s)$ units of risky asset holding at date $t = 2$.

The second constraint lines up the bank's assets with its liabilities. The third constraint shows the bank's anticipation of the solution to the household's problem at date $t = 1$ as the household is risk neutral, which makes the solution to be at the corner as we saw in Proposition 1. The final constraint defines the threshold.

2.3.3 Solution to the transparent bank's problem

I characterize the solution to the bank's problem in Proposition 2.

Proposition 2. [Solution to the Transparent Bank's Problem] *Let l^* denote the optimal choice of the bank's risky asset holding l. Then the solution to the bank's problem, l^* and $s^* = m_0 + n_0 - l^*$ can be characterized as follows:*

- *If the deposit is information-insensitive and there is no withdrawal, the marginal benefit of increasing l is always bigger than the marginal cost. The solution is at the corner and l is increased until $\mathbb{E}[\theta] = \theta^*$:*

$$l^* = \frac{\theta^* m_0 - m_0 - p_{low}[r^s(m_0 + n_0) - rm_0 + n_0]}{p_{low}(z_{low} - r^s)}$$

- *If the deposit is information-sensitive and there is a withdrawal, but the withdrawal is small enough that the bank can pay the household off by liquidating only the safe asset, the marginal benefit of increasing l is always bigger than the marginal cost. The solution is at the corner and l is increased until $\mathcal{W} = s$:*

$$l^* = n_0 - rm_0$$

- *If the deposit is information-sensitive and there is a big withdrawal that the bank has to liquidiate not only the safe asset but also the risky asset the marginal cost of increasing l is always bigger than the marginal benefit. The solution is at the corner and l is decreased until either $\mathcal{W} = s$ or $\mathbb{E}[\theta] = \theta^*$:*

$$l^* = \max\left\{ \frac{\theta^* m_0 - m_0 - p_{low}[r^s(m_0 + n_0) - rm_0 + n_0]}{p_{low}(z_{low} - r^s)}, n_0 - rm_0 \right\}$$
$$= n_0 - rm_0$$

Whether the bank wants to keep the deposit information-insensitive by reducing the risky asset holding or is content with the deposit turning information-sensitive to increase the expected return on its asset depends on the specific parameters of the model. This paper does not take a stance on this issue. However, throughout the rest of the paper, I focus on the more interesting nontrivial case of when the deposit is kept information-insensitive and serves the role of money (i.e. the first case in Proposition 2). In this case, the household derives direct utility not only from consuming but also from holding the deposit.

When the deposit turns information-sensitive and loses its value as money (the second and third cases in Proposition 2), the household withdraws from the bank, and the bank's optimal choice is invariant to the household's preferences. When the deposit is information-insensitive, and it maintains its value as money, the optimal solution of the bank is characterized in terms of the withdrawal threshold θ^*, which in turn is a function of the model's primitives (β, α, and r).

The bank's optimal choice of risky asset holding l^* is negatively related to parameters that make the household more willing to hold the deposit. When the household is patient that it is willing to delay consumption for the deposit's added benefit as money (β high), it is optimal for the bank to reduce its investment in the risky asset in order to maintain the deposit's information-insensitivity and its role as money. Likewise, when the household's preference for money holding is high (α high), the bank optimally reduce its l to keep the deposit's value as a transactional medium.

2.4 Opaque Bank: Household's Inference Problem of Determining θ

In this subsection, I analyze the opaque bank and investigate the implications of opacity on the bank's portfolio choice. I first present the household's inference problem of determining the deposit's moneyness θ at the beginning of date $t = 1$. Then I see how the solution to the bank's problem changes compared to when the bank is transparent.

2.4.1 Setup of the household's inference problem

The bank is opaque in the spirit of Dang et al. (2017). In order to maintain the information-insensitivity of the deposit, the bank limits the information about its asset portfolio from flowing to the household. The bank opacity is characterized in the model as follows.

Assumption 3. [Bank opacity]

1. *The household has a diffuse prior about the bank's date $t = 1$ asset allocation decision.*

2. *At date $t = 1$, the bank can credibly announce its ROE, and this is the only information that the household has about the bank.*

Assumption 3 is reasonable given how financial institutions disclose as little information as possible about the left-hand side of their balance sheet to the public.[12]

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[12]Papers like Almeida et al. (2014) and Darmouni and Mota (2022), for example, point out this issue.

At the beginning of date $t = 1$, the bank privately observes how the shock z to the risky asset holding l is going to be realized as at date $t = 2$.[13] Let $\tilde{z}_i$ denote the realized z where i denotes the three states: $i \in \{H, M, L\}$. Let r^s denote the return on the safe asset. Without loss of generality, I assume $z_H > z_M > r^s > z_L$ and $\mathbb{E}[z] > r^s$.

The bank marks-to-market the value of its asset based on its observation of $\tilde{z}_i$ to calculate its profit for date $t = 1$ as follows:[14]

$$\pi(\tilde{z}_i) = \tilde{z}_i l + r^s s - r m_0 \tag{2}$$

The bank announces its ROE to the household. [15] The household perceives the deposit's moneyness by calculating θ based on the bank's announcement of its ROE. In particular, the household does *not* know the realized z nor the bank's asset allocation choice of l and s.

2.4.2 Household's inference of the bank's risky asset holding

The household only knows the probability distribution of z and the bank's ROE. Therefore, in order for the household to determine what proportion of the deposit is riskless and thus serves the role of money (due to Assumption 1), it makes an educated guess about how the bank allocated its assets at date $t = 0$ based on the information available to them.

Let l^E denote the household's estimate of the bank's risky asset holding as opposed to l, which is the bank's actual risky asset holding. l^E is calculated as follows. Start from the bank's ROE announcement using Equation (2) and plug in the balance sheet identity

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[13]This is in contrast to the case of the transparent bank that we saw earlier where the household directly knows the realized z.

[14]Unrealized gains or lossed on the bank's assets are also accounted for when banks calculate the net income or profit for the quarter/year as banks have to mark-to-market their assets. One can think of the bank's privately observing how z is going to be realized as at date $t = 2$ and announcing it as a part of π at date $t = 1$ as accounting for unrealized gains or losses on its assets.

[15]In the real world context, the bank's announcing π can be analogous to a bank doing an earnings call. During an earnings call or in public filing such as 10-K's or 10-Q's the bank announces high-level numbers like the profit for the quarter without getting into what type of asset it is holding. The bank does not specifically inform the investors exactly how much of the bank's resources are in exotic derivatives (risky asset holding l), for example.

$s = n_0 + m_0 - l$:

$$ROE(\tilde{z}_i) \equiv \underbrace{\frac{\pi(\overbrace{\tilde{z}_i}^{\text{unobservable}})}{n_0}}_{\text{observable}} = \frac{\tilde{z}_i l + r^s s - r m_0}{n_0}$$

$$= \frac{\overbrace{\tilde{z}_i}^{\text{unobservable}} \overbrace{l}^{\text{unobservable}} + r^s(m_0 + \overbrace{n_0}^{\text{observable}} - \overbrace{l}^{\text{unobservable}}) - r m_0}{n_0}$$

$$(3)$$

where I indicate what variables are observable to the household and what variables are not. It's important to note that the household *does* observe the bank's ROE π/n, but *does not* observe the shock $\tilde{z}_i$ that makes up the profit π. From Equation (3), the household can solve for l as follows:

$$l = \frac{\overbrace{ROE(\tilde{z}_i)n_0}^{\text{observable}} - r^s(m_0 + n_0) + r m_0}{\underbrace{\tilde{z}_i}_{\text{unobservable}} - r^s}$$

$$(4)$$

As $\tilde{z}_i$ is unobservable to the household, l that is on the left-hand side of Equation (4) is a random variable to the household. Given the announced ROE and the probability distribution of z, the household can calculate an estimate for l–denoted l^E–as follows:

$$l^E(\tilde{z}_i) \equiv \sum_{j \in \{H,M,L\}} p_j \left(\frac{\overbrace{ROE(\tilde{z}_i)n_0}^{\text{observable}} - r^s(m_0 + n_0) + r m_0}{\underbrace{z_j}_{\text{random variable}} - r^s} \right)$$

$$(5)$$

for $i \in \{H, M, L\}$. In order to come up with an educated guess of what l is, the household considers all three states being realized by weighing random variable l for each state with the probability distribution of z.

Let's consider the following example. Suppose the high state was realized so that $i = H$. The bank then can calculate its date $t = 1$ profit as $\pi(\tilde{z}_H)$ and announces it to the household. After observing $\pi(\tilde{z}_H)$, the household solves for l as in Equation (4). However, the household does not know if the profit $\pi(\tilde{z}_H)$ was due to the state being high, medium, or low. Since the household does have access to the probability distribution of z, the household makes an educated guess about what l is by weighing the backed out l from Equation (4) by the probability distribution of z.

It is important to distinguish $\tilde{z}_i$ from z_j's in the denominator in Equation (5). $\tilde{z}_i$ is the

realized z that the household does not observe, and z_j's are the household's guesses of what the realized z is. In Equation (5), the household weighs these guesses of z's with the probability distribution of z to infer what l would be. Intuition for l^E construction is further explained in Appendix E. An alternative construction process for l^E when the household is only considering the worst-case scenario of being the most exposed to the bank's risky asset holding l is presented in Appendix G.

2.4.3 Relationship between l^E and l depends on the level of bank opacity

We saw in Proposition 1 that how θ compares to the threshold θ^* determines the household's optimal decision at date $t = 1$. Therefore, analyzing how the bank's asset allocation decision at date $t = 0$ affects θ, thereby determining the household's withdrawal decision at date $t = 1$ and the bank's asset liquidation need, is crucial to solving for the bank's optimal date $t = 0$ choice.

l^E is ultimately what determines θ. Therefore, how the bank's choice of l affects the household's estimate l^E is a crucial mechanism that we need to study. From the perspective of the bank at date $t = 0$ making its asset allocation decision, the bank's choice of risky asset holding l is related to the household's estimate l^E as follows:[16]

$$\mathbb{E}_0[l^E(z)] = l * \mathcal{T} \tag{6}$$

where the variable $\mathcal{T}$[17]

$$\mathcal{T} \equiv \mathbb{E}[z - r^s]\mathbb{E}\left[\frac{1}{z - r^s}\right]$$

is defined to be the variable that represents the bank's opacity.[18] l is related to l^E in expectation because we are looking at the relationship between the two variables at date $t = 0$ when the bank is making its asset allocation decision.

The household has to infer l with limited information about the bank–its ROE and the probability distribution of z. Suppose the bank realized a higher profit even though the state was realized to be $z = \tilde{z}_M$ because they invested heavily in the risky asset l. Even if this is the case, because the bank is opaque, the household has to take into account the possibility that the profit is high not because the bank is heavily invested in the risky asset l but because it was lucky and was hit with a good return shock $z = \tilde{z}_H$. Compared to the scenario when the profit is high due to a higher l, if the profit is high because $z = \tilde{z}_H$, the

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[16]This equation can be obtained by taking an expectation on the both sides of Equation (5). Derivation in the proof for Proposition 2.

[17]$\mathcal{T}$ stands for bank "transparency." A decrease in $\mathcal{T}$ corresponds to a higher degree of bank opacity.

[18]Derivation for $\mathcal{T}$ shown in the proof for Proposition 2.

household's estimate l^E is lower than the actual l. This kind of discrepancy between l and l^E due to the bank being opaque is defined as the variable $\mathcal{T}$. A lower $\mathcal{T}$ (transparency) is defined to correspond to a higher opacity.[19]

Looking at Equation (6), we can see that if $\mathcal{T}$ is lower, or in other words when the bank is more opaque, the bank can increase their allocation of resources more towards risky asset holding without affecting l^E that much. When $\mathcal{T}$ is high, a marginal increase in the bank's risky asset holding will increase the expected l^E by less than when $\mathcal{T}$ is high. This means the lower the $\mathcal{T}$ is, the less significant the effect of a change in the bank's risky asset holding is on the deposit moneyness θ because l's effect on θ is through its effect on l^E.

2.4.4 θ construction

Given its estimate of the bank's risky asset holding l^E and the bank's announcement of its equity base n_0, the household can calculate θ, which denotes the proportion of the deposit that is riskless. Per Assumption 1, the household needs to determine what proportion of the deposit is riskless in order to determine the deposit's moneyness. Without loss of generality, I make the following parametric assumption about the bank insolvency.

Using l^E, the household can make an inference about what proportion of the deposit is riskless thus serves the role of money. We can define θ as follows:

Definition 2. [Definition of θ for an opaque bank] θ denotes the proportion of deposit m_0 that the household thinks is risky:

$$
\theta(z) \equiv 1 + \underbrace{\frac{p_L * \overbrace{\{\tilde{z}_L l^E(z) + r^s[m_0 + n_0 - l^E(z)] - rm_0 + n_0\}}^{\text{(1) how much deposit is lost in the low state given the calculated } l^E}}{m_0}}_{\text{(2) the proportion of deposit that is expected to be lost and thus is not money}} \tag{7}
$$

The difference between Equation (7) when the bank is opaque and Equation (1) when the bank is transparent is that instead of using its knowledge of l to calculate θ, the household uses its estimate of l to calculate θ. Given this construction process for θ and assuming no short-selling for risky asset holding, I can show that θ is decreasing in l for all z.

Lemma 1.

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[19]This definition is verified in the data in Appendix 3.3.3 when I compared an opaque and a transparent banks. In the following section when I present the bank's problem, I compare the opaque versus transparent banks and their implications for the optimal asset allocation.

- θ is decreasing in l, or $\frac{\partial \theta}{\partial l} \leq 0$ for all z.

- θ is decreasing in bank ROE, or $\frac{\partial \theta}{\partial ROE} \leq 0$ for all z.

- m_1 is decreasing in l, or $\frac{\partial m_1}{\partial l} \leq 0$ for all z.

- m_1 is decreasing in bank ROE, or $\frac{\partial m_1}{\partial ROE} \leq 0$ for all z.

Lemma 1 holds because even in the good state of the world, the household is constantly worried about the tail risk of a portion of their safe assets becoming risky and turning information-sensitive. A higher ROE can also materialize due to a lower equity base. A lower bank equity means that the buffer between safe asset investors and bank insolvency is smaller. This increases the possibility that the bank is insolvent when the bad shock is realized. As can be seen in Equation (7), all else equal, a lower n_0 leads to a lower θ, thus a lower m_1.

Lemma 1 gives us some empirical predictions that we can test in data.

Prediction 1. *An increase in the bank's realized ROE results in depositors withdrawing from the bank (lower m_1).*

Prediction 2. *An increase in the bank's realized ROE results in lower moneyness of the deposit that it issues (lower θ).*

2.4.5 θ construction intuition

Making a connection to the real world, Assumption 1 and the construction process of θ reflect the concerns of safe asset investors such as money market mutual funds, sovereign wealth funds, or pension funds that invest heavily in privately produced money-like safe assets like repurchase agreement or commercial paper. These investors need a form of investment vehicle that is money-like; i.e. safe and liquid, even if they have to compensate the issuers by accepting a lower interest rate for providing monetary services. Financing themselves by issuing money-like safe assets is a profitable endeavor for banks because they can get cheap debt financing.

In this environment, a better performance of a bank in terms of a higher return on equity (ROE) is not particularly good news to the safe asset investors. A higher ROE of a bank indicates a higher profit or a lower equity base. The upside to the bank's higher profit is fixed ex-ante to the interest rate promised. However, the downside of holding the safe assets is complete insolvency of the bank and at least a portion of the safe assets not being able to be paid back because the bank is more likely to be engaged in riskier

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investment activities. Therefore, even in the good state of the world, safe asset investors are constantly wary about the left tail event. This is reflected in the household caring only about the possibility of the low state realizing when it is constructing θ as shown in Equation (7).

2.4.6 Solution to the Opaque Bank's Problem

The following proposition presents the solution to the opaque bank's problem.

Proposition 3. [Solution to the Opaque Bank's Problem] *Let l^* denote the optimal choice of the bank's risky asset holding l. Then the solution to the bank's problem, l^* and $s^* = m_0 + n_0 - l^*$ can be characterized as follows:*

- *If the deposit is information-insensitive and there is no withdrawal, the marginal benefit of increasing l is always bigger than the marginal cost. The solution is at the corner and l is increased until $\mathbb{E}[\theta] = \theta^*$:*

$$l^* = \frac{\theta^* m_0 - m_0 - p_{low}[r^s(m_0 + n_0) - rm_0 + n_0]}{p_{low}(z_{low} - r^s)\mathcal{T}}$$

- *If the deposit is information-sensitive and there is a withdrawal, but the withdrawal is small enough that the bank can pay the household off by liquidating only the safe asset, the marginal benefit of increasing l is always bigger than the marginal cost. The solution is at the corner and l is increased until $\mathcal{W} = s$:*

$$l^* = n_0 - rm_0$$

- *If the deposit is information-sensitive and there is a big withdrawal that the bank has to liquidiate not only the safe asset but also the risky asset the marginal cost of increasing l is always bigger than the marginal benefit. The solution is at the corner and l is decreased until either $\mathcal{W} = s$ or $\mathbb{E}[\theta] = \theta^*$:*

$$l^* = \max\left\{\frac{\theta^* m_0 - m_0 - p_{low}[r^s(m_0 + n_0) - rm_0 + n_0]}{p_{low}(z_{low} - r^s)\mathcal{T}}, n_0 - rm_0\right\}$$
$$= n_0 - rm_0$$

Notice the the only difference between the solution to the transparent bank's problem and the opaque's bank's problem is the bank opacity variable $\mathcal{T}$ that is in the denominator

of the expression for l^*. When the bank is transparent, or in other words when $\mathcal{T} = 1$, l^* for an opaque bank is equal to l^* for a transparent bank. As the bank becomes more and more opaque or as $\mathcal{T}$ decreases, l^* for an opaque bank gets bigger and bigger relative to l^* for a transparent bank. In other words, when the bank is more opaque, the bank can increase its holding of the risky asset without affecting the deposit moneyness as much. This fact will be investigated further in the following section.

2.5 Opaque Bank vs. Transparent Bank

In this section, I compare the results I have obtained analyzing the opaque and transparent bank and investigate the implication of bank opacity.

When the bank is transparent, the household knows exactly how exposed the bank is to the tail risk of insolvency. An increase in the bank's holding of the risky asset decreases profit in the low state, therefore decreasing the deposit's moneyness θ *one-for-one*. Proposition 4 examines how changes in l differentially affects the moneyness of the deposit θ when the bank is opaque versus when it is transparent.

Proposition 4. *Let θ_O denote the moneyness of the opaque bank deposit and θ_T denote the moneyness of the transparent bank deposit. Then θ_O is less responsive to changes in l and bank ROE than θ_T; i.e.*

$$\left| \frac{\partial \theta_O}{\partial l} \right| < \left| \frac{\partial \theta_T}{\partial l} \right|$$

and

$$\left| \frac{\partial \theta_O}{\partial ROE} \right| < \left| \frac{\partial \theta_T}{\partial ROE} \right|$$

The intuition of Proposition 4 is as follows. Using the chain rule, the derivative of θ_O with respect to l can be written as follows:

$$\frac{\partial \theta_O}{\partial l} = \frac{\partial \theta_O}{\partial l^E} \frac{\partial l^E}{\partial l}$$

It is easy to see that $\partial \theta_O / \partial l^E = \partial \theta_T / \partial l$, which means the inequality in Proposition 4 holds because changes in l affect θ through l^E for opaque banks while changes in l affect θ directly for transparent banks.

Suppose that the bank chooses a higher level of l at date $t = 0$ and the economy is in the medium state $z = \tilde{z}_M$. If the bank is opaque, the household cannot figure out whether the profit announced at date $t = 1$ is due to a higher l or a higher z. The household should consider the case when $z = \tilde{z}_H$, and the inferred l^E is less than the actual l. The household should also consider the case when $z = \tilde{z}_L$, which means l should be close to zero. This

Figure 2: Opaque Bank vs. Transparent Bank
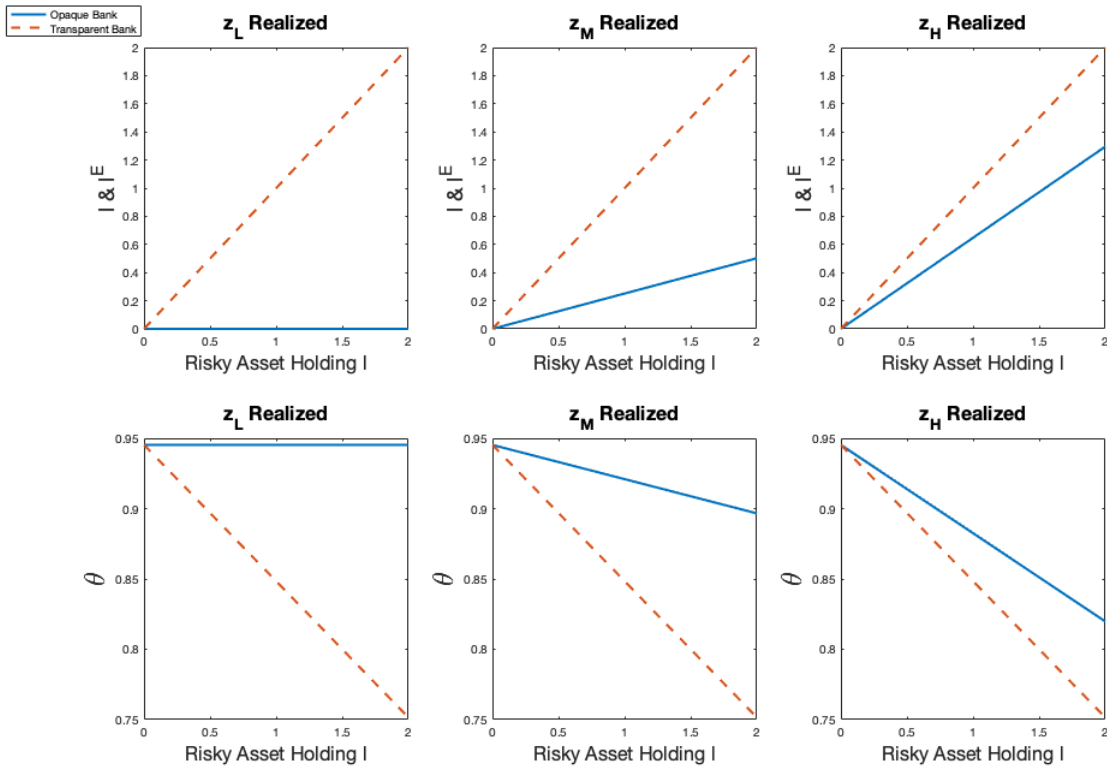
Notes: The blue solid line plots the behavior of an opaque bank, and the orange dashed line plots the behavior of a transparent bank. Top three figures plot the household's estimate l^E of the risky asset holding against the actual risky asset holding for each realized state. Bottom three figures plot the deposit's moneyness θ against the bank's risky asset holding l and compare how the sensitivity of θ to l differs according to whether the bank is opaque or transparent for each realized state. Parameters used are as follows: $p_H = 0.3$, $z_H = 0.5$, $p_M = 0.3$, $z_M = 0.2$, $p_L = 0.4$, $z_L = -0.45$, $r^s = 0.01$, $m_0 = 19$, $n_0 = 0.1$.

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also makes the inferred l^E to be less than the actual l. On the other hand, if the bank is transparent, the household observes that a higher level of l is chosen, determines that it has a higher exposure to the bank insolvency, and lowers θ further than when the bank is opaque. This leads to the relationship $|\partial\theta_O/\partial l| < |\partial\theta_T/\partial l|$ that we saw in Proposition 4

This intuition of Proposition 4 is visualized in Figure 2. The blue solid line plots the behavior of an opaque bank, and the orange dashed line plots the behavior of a transparent bank. The top three figures plot the household's estimate l^E of the risky asset holding against the actual risky asset holding for each realized state. We can see that for each realized state, $l^E < l$ because the household needs to take into consideration each state being realized. Furthermore, we can see that comparing across states, l^E is higher when z is higher because a higher z means a higher realized profit, which means the household revises upward their estimate of l.

The bottom three figures plot the deposit's moneyness θ against the bank's risky asset holding l and compare how the sensitivity of θ to l differs according to whether the bank is opaque or transparent for each realized state. We can see that for each realized state of the world, the deposit's moneyness θ is less responsive to changes in l when the bank is opaque than when it is transparent. As a result, the deposit's moneyness θ when the bank is opaque is always above θ when the bank is transparent. This is because a unit increase in the bank's risky asset holding is reflected in l^E by less than a unit, as we can see in the top three plots.

The result presented in Proposition 4 gives us the following empirical predictions that we can test in data.

Prediction 3. *When the bank is more opaque, the deposit's moneyness is less sensitive to the riskiness of the bank's balance sheet and changes in the bank's ROE, which means the depositor's investment decision is less sensitive to the riskiness of the bank's balance sheet and changes in the bank's ROE.*

2.6 Private Optimality of Opacity for the Bank

The fact that the responsiveness of the deposit moneyness is lower when the bank is opaque than when the bank is transparent implies what the optimal strategy is when the bank is trying to decide if it wants to be opaque or transparent.

Proposition 5. *Let l_O^* and l_T^* denote the optimal choice of the bank's risky asset holding l when the bank is opaque and transparent, respectivly. If the deposit is information-insensitive that there is no withdrawal, then*

$$l_T^* < l_O^*$$

If this is the case, it is optimal for the bank to be opaque.

Proposition 5 holds due to the result established in Proposition 4: the moneyness of an opaque bank-issued deposit is less responsive to changes in l than that of a transparent bank-issued deposit. When the bank is opaque, it has more leeway to increase its risky asset holding without making the deposit less money-like. This is always optimal for the bank as $\mathbb{E}[z] > r^s$. This is because the household has to take into account a higher profit resulting not only from a higher l but also from the pure luck of getting hit with a higher z. This makes the household less responsive to an increase in l than when the bank is transparent.

The result presented as Proposition 5 gives us the following empirically testable prediction.

Prediction 4. *The bank's assets are riskier if the bank is more opaque.*

2.7 Welfare Implications of Bank Opacity

In this subsection, I solve the social planner's problem and show that the opacity of the bank is not only privately optimal for the bank but also socially optimal. The objective of the social planner is to choose the bank's asset allocations as well as the household's consumption-saving allocations to maximize the weighted sum of the household's and the bank's utilities. The welfare function Ω at time $t = 0$ is as follows:

$$\Omega = \begin{cases} \kappa\{\underbrace{\beta(1+r)^2 m_0 + \alpha\mathbb{E}_0[\theta]m_1}_{\text{household utility}}\} \\ +(1-\kappa)\{\underbrace{\mathbb{E}_0[1+z]l + s - rm_0 - (1+r)m_1}_{\text{bank final period net worth}}\} & \text{if } \mathbb{E}_0[\theta] \geq \theta^* \text{ and } \mathcal{W} = 0 \\ \kappa\{(1+r)m_0 + \alpha\mathbb{E}_0[\theta]m_1\} \\ +(1-\kappa)\{\mathbb{E}_0[1+z]l + (s-\mathcal{W})\} & \text{if } \mathbb{E}_0[\theta] < \theta^* \text{ and } \mathcal{W} < s \\ \kappa\{(1+r)m_0 + \alpha\mathbb{E}_0[\theta]m_1\} \\ +(1-\kappa)[\mathbb{E}_0[1+z](l-\{\mathcal{W}-s\}) - \delta(\mathcal{W}-s)\} & \text{if } \mathbb{E}_0[\theta] < \theta^* \text{ and } \mathcal{W} > s \end{cases}$$

where κ denotes the welfare weight. The social planner chooses the bank's asset allocation l and s as well as the household's consumption c_1, c_2, and withdrawal $\mathcal{W}$ to maximize the welfare function Ω.

When the bank is solving its problem case-by-case, it does not internalize the effect that a marginal increase in risky asset holding l has on the overall transactional benefit

that the deposit provides, which affects the household's welfare. This is salient especially for the case when the deposit is information-insensitive and the household is holding the deposit as the level of θ directly affects the household's utility. On the other hand, when the social planner is solving its problem, it takes into account the effect of a marginal increase in l on not only the bank's final period net worth but also the usefulness of the deposit as money.

Comparing the first order conditions of the bank's and the social planner's problem with respect to the bank's risky asset holding l lets us see this difference. The bank problem's first order condition with respect to l is as follows:

$$\mathbb{E}_0\left[\frac{\partial n_2}{\partial l}\right] = 0 \tag{8}$$

while the social planner problem's first order condition with respect to l is as follows:

$$\mathbb{E}_0\left[\kappa\alpha\frac{\partial\theta}{\partial l}m_1 + (1-\kappa)\frac{\partial n_2}{\partial l}\right] = 0 \tag{9}$$

We can see that as opposed to the bank's first order condition with respect to l, the social planner's first order condition with respect to l has an extra term that corresponds to the risky asset holding l's impact on the moneyness of the deposit. We can decompose the effect of a marginal increase in l on welfare by solving for $\mathbb{E}_0[\partial n_2/\partial l]$ in Equation (9) as follows:

$$\underbrace{\mathbb{E}_0\left[\frac{\partial n_2}{\partial l}\right]}_{\text{internalized by the bank}} + \underbrace{\frac{\kappa}{1-\kappa}\alpha m_1\mathbb{E}_0\left[\frac{\partial\theta}{\partial l}\right]}_{\text{uninternalized by the bank}} = 0 \tag{10}$$

The first term of Equation (10) quantifies the effect of increasing a unit of risky asset holding l that is internalized by the bank. As the expected return of the risky asset is bigger than that of the safe asset, this term is positive, which means a marginal increase in l has a positive effect on welfare. On the other hand, the second term in this equation quantifies the effect of increasing a unit of risky asset holding l that is not internalized by the bank. As shown in Lemma 1, $\mathbb{E}_0[\partial\theta/\partial l] < 0$, which means the uninternalized effect of a marginal increase in l on welfare is negative.

Let the second term of Equation (10) be denoted as $\mathcal{M}$

$$\mathcal{M} \equiv \frac{\kappa}{1-\kappa}\alpha m_1\mathbb{E}_0\left[\frac{\partial\theta}{\partial l}\right] \tag{11}$$

which measures the inefficiency from the bank's failure to internalize the effect of investing in the risky asset. We can see that the inefficiency associated with a marginal increase

in the risky asset holding l is higher when the household values the deposit more as a form of private money (α is higher), when the household holds more deposit (m_1 is higher), and if the deposit's moneyness is more responsive to changes in the risky asset holding l ($\mathbb{E}_0[\partial\theta/\partial l]$ is higher in absolute value). In order for the bank's private asset allocation decision to be closer to being efficient, l and s have to be chosen such that $\mathcal{M}$ is close to zero.

As before, I conduct the welfare analysis case-by-case. In Proposition 1, we saw that if $\theta < \theta^*$ and the deposit turns information-sensitive, there is a withdrawal at date $t = 1$. This means $\mathcal{W} = (1+r)m_0$ or $m_1 = 0$. As the household does not hold any deposit going from date $t = 1$ to date $t = 2$, changes in the deposit moneyness θ do not affect their welfare. Looking at the definition of $\mathcal{M}$ above in Equation (11), we can see that $m_1 = 0$ makes $\mathcal{M} = 0$. This means when the household is withdrawing everything and holding no deposit going from date $t = 1$ to date $t = 2$, the bank's private choice of its asset allocation is welfare maximizing.

Let's consider the more interesting case when $\theta > \theta^*$ so that the deposit remains information-insensitive and there is no withdrawal at date $t = 1$. If this is the case, $\mathcal{W} = 0$ and $m_1 = (1+r)m_0$, which means the moneyness $\mathcal{M} > 0$, and the bank's private choice of its asset allocation is inefficient. Now let's compare the cases when the bank is opaque versus transparent. We saw in Proposition 5 above that the moneyness of the deposit issued by an opaque bank is less responsive to changes in the risky asset holding l than that issued by a transparent bank; i.e.

$$\left|\frac{\partial\theta_O}{\partial l}\right| < \left|\frac{\partial\theta_T}{\partial l}\right|$$

where θ_O (θ_T) denotes the moneyness of the deposit issued by an opaque (transparent) bank. Therefore, it follows immediately that when the bank is opaque, the inefficiency resulting from the bank's failure to internalize its choice of l on θ should be smaller.

Proposition 6. *Let $\mathcal{M}_O$ and $\mathcal{M}_T$ denote the moneyness wedge when the bank is opaque and transparent, respectively. Then*

$$|\mathcal{M}_O| < |\mathcal{M}_T|$$

which means the competitive allocations when the bank is opaque is more efficient than those when the bank is transparent.

We saw in Proposition 5 that it is privately optimal for the bank to be opaque. By being opaque, it can increase its risky asset holding l more than when it is transparent. Holding a higher level of l is optimal for the bank, as the expected return from holding

the risky asset is higher than that from holding the safe asset, and the bank is risk neutral. The result in this section presented in Proposition 6 above suggests that it is not only privately optimal but also socially optimal for the bank to be opaque.

It is inefficient for the bank to hold more risky assets because the bank does not internalize the effect of its asset allocation decision on the transactional benefit of the deposit. A higher l means the bank is more exposed to the tail risk of the risky asset. When the bank is transparent, the effect of marginally increasing l is immediately observed by the household and directly reflected as a decrease in θ. However, when the bank is opaque, the household does not observe an increase in l. Therefore, the household needs to take into consideration the possibility that the expected profit was high not because l was high but because the bank got lucky and the exogenous shock z was high. When the bank is opaque, a marginal increase in l will not affect the deposit's moneyness θ as much as when the bank is transparent, making an opaque bank's moneyness wedge closer to zero than a transparent bank's moneyness wedge.

More broadly, bank opacity resolves the inefficiency caused by the household prematurely panicking and running on the bank in response to a slight uptick in the bank asset portfolio's riskiness. The household can allow itself to hold on to desirable money-like safe assets without having to worry about those assets losing moneyness. It prevents a financial crisis that is instigated by a mere bank liquidity event.

2.8 Summary and Empirical Predictions

In the empirical analysis section of the paper that follows, I study funding relationships between dealer banks and money market mutual funds, which are, respectively, one of the most active issuers and holders of privately produced money-like safe assets. Empirical predictions that I have presented throughout the section is summarized and reformulated to fit the context of my empirical setting as follows.

In this empirical setting, I test the following implications from the model.

Prediction 1. *An increase in a dealer bank's realized ROE results in MMFs withdrawing from the bank.*

Prediction 2. *MMFs withdraw from higher ROE dealer banks because higher ROE banks produce safe asset that is less money-like.*

From Equation (5) we can see that l^E is increasing in the bank's ROE. When the bank announces a higher ROE, the household interprets this signal to mean that the bank is invested more heaviliy on the risky asset; i.e. the household's estimate of the risky asset

l^E is higher. This results in lower deposit moneyness as can be seen in Equation (7) as the household only cares about the state of the world when bank equity is completely wiped out and redeemability of the deposit is in question; i.e. the low L state.

The investors in privately produced money-like safe assets such as money market mutual funds care especially about the tail risk when the bank becomes insolvent and at least a portion of their deposit would not be able to be paid back. Even if the bank that these investors put their money in becomes profitable, the upside of the bank's better performance for these kinds of investors is limited to the interest rate promised ex ante. To these kinds of investors, a higher profit means a bigger investment in risky assets that have a higher expected return (a higher l in the model's context), which increases the bank's exposure to the tail risk. Also, a lower equity base means a smaller buffer between them and the bank insolvency.

Prediction 3. *A MMF's investment decision is less responsive to changes in a dealer bank's ROE when the bank is more opaque because the deposit's moneyness is less responsive to changes in a dealer bank's ROE when the bank is more opaque.*

Banks are optimally opaque to maintain the information-insensitivity of privately produced safe assets thereby facilitating their use as private money. The prerequisite to these assets being able to serve the role of money is them almost always trading at par. However, maintaining these assets' value at par is a tall task as banks' objective is to maximize profit by investing in assets with a higher expected return that are also more volatile. Considering that left hand side of banks' balance sheets are effectively a collateral for privately produced safe assets, if money market mutual funds realize that the volatility of banks' assets is higher, it is harder for them to value their holdings of privately produced safe assets at par. This misaligned incentive between banks and money market mutual funds is why banks need to keep detailed information about the asset side of the balance sheet away from the money market mutual funds. Banks don't want money market mutual funds to find out they are invested heavily on risky assets to sustain the moneyness of the privately produce safea asset thereby maintaining the debt funding from money market mutual funds. This means if a bank wants to hold riskier assets but also wants to maintain its ability to finance itself by issuing money-like safe assets, it needs to be more opaque.

Prediction 4. *A dealer bank's assets are riskier if it is more opaque.*

In the model's context, the opacity of a bank made the household take into account that a better performance of a bank might not entirely because the bank is invested heavily

in risky assets but because of a mere good luck in terms of a higher realization of z, which the money market funds (the households) cannot distinguish. The bank's opacity makes a unit increase in the bank's realized ROE result in an increase in the money market mutual fund's (the household's) estimate of the bank's risky asset holding l^E by less than a unit as they need to take into account the possibility of a higher realization of z. As money market mutual funds are not as quick to update the moneyness of the privately produced safe asset following a change in banks' profit, banks have more leeway to increase their risky asset holding, which is optimal for them as the expected return on the risky asset is higher than that on the safe asset (Proposition 4 and Proposition 5).

3 Empirical Analysis

In this section, I test the model predictions. In particular, I explore the wholesale banking sector and look at funding relationships between money market mutual funds (MMFs) and dealer banks, which are, respectively, one of the most active issuers and holders of money-like safe assets.[20]

Previous results in papers like Chen et al. (2022) show that an increase in ROE of a commercial bank results in deposit *inflow* into that bank from retail depositors.[21] I show that in the case of wholesale deposits, where the depositors like money market fund managers are more informed, the empirical pattern turns out to be the opposite.

I first argue that a dealer bank's ROE is a significant metric that predicts moneyness of safe assets issued by that bank. I show that when a dealer bank's ROE goes up, MMFs actually decide to withdraw from that bank. I also argue that dealer bank ROE affects MMFs' investment decision through its effect on safe asset moneyness. An increase in a dealer bank's ROE leads to a deterioration in safe asset moneyness issued by that bank. Finally, I show that the ROE's effect on MMFs' investment decisions and safe asset moneyness is nonlinear: the effect becomes stronger when dealer bank ROE is already high.

3.1 Data

The issuers of privately produced money-like safe assets that I focus on are dealer banks that fund their portfolios of assets by issuing short-term debt such as repurchase agreement and commercial paper. Specifically, I focus on the Federal Reserve Bank of New

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[20]For example, as of December 2021, Goldman Sachs alone had issued $165.88 billion worth of repo to finance its investment activities.

[21]Chen et al. (2022) only considers uninsured deposits, which means the existence of deposit insurance did not affect this result.

York's primary dealers. [22] The holders of the money-like safe asset are investors who need safe and liquid forms of investment vehicles. I focus on MMFs, which are one of the major players in the money market.[23]

The primary dataset on MMFs that I use is Informa Financial Intelligence's iMoneyNet. iMoneyNet data contain balance sheet information on the near-universe of MMFs in the United States. The data is based on the N-MFP form, which is a publicly available filing that every MMF is required to make to the SEC. In particular, it contains information on the type of assets that the MMFs hold, the value of such assets, and importantly who the issuers of those assets are. The N-MFP form was created in May of 2010 in the aftermath of the Global Financial Crisis. In this paper, I focus on August of 2011 to December of 2021.

The goal of the empirical exercise is to see the implications of bank opacity by looking at how movements in public information about a dealer bank affects MMFs' investment decisions. Public information about a company can be obtained in its routine regulatory filings such as the Call Reports or the 10-Q filings. I merge the iMoneyNet MMF asset holding data with the Call Report data and the Compustat quarterly data that contains balance sheet information about the dealer banks. As the iMoneyNet data has information about the issuers of the assets held by each MMF, I can directly match the MMF asset holding data with the balance sheet data of the dealer bank that issued the asset period-by-period and asset-by-asset. With this combined data I can see how a movement in various balance sheet variables, including the key variable of ROE, affects MMFs' investment decisions.
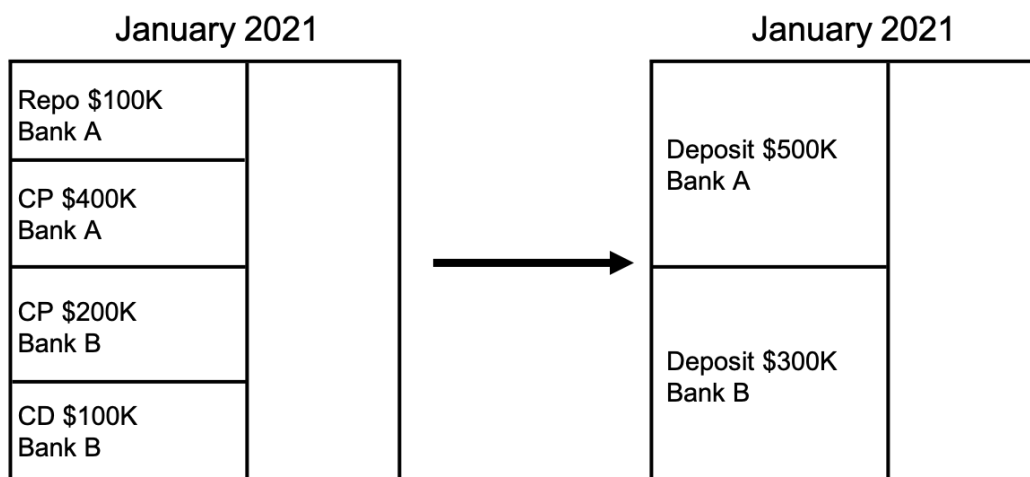
3.2   Construction of Key Variables

I construct two variables and use them as my main dependent variables. First, I construct a variable called "Deposit" by aggregating each MMF's holding of safe assets issued by each dealer bank to a monthly level. The deposit variable proxies for MMFs' investment decisions. I call the aggregated MMF portfolio variable a "Deposit" because an MMF buying a money-like safe asset from a dealer bank is equivalent to the MMF depositing their money to the dealer bank.

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[22]Bank of Nova Scotia, BMO Capital Markets Corp., Barclays Capital Inc., BofA Securities, Inc., Citigroup Global Markets Inc., Credit Suisse AG, Deutsche Bank Securities Inc., Goldman Sachs & Co. LLC, HSBC Securities Inc., J.P. Morgan Securities LLC, Morgan Stanley & Co. LLC, UBS Securities LLC, Wells Fargo Securities, LLC. The rest of the primary dealers do not have the Compustat data or the iMoneyNet data available.

[23]Examples of MMFs in my data include Fidelity, Alliance Bernstein, PIMCO, and Blackrock. Overall, there are 56 MMFs in the data.

Figure 3: Deposit Variable Construction Example

Notes: The figure illustrates how I construct the deposit variable that I use to proxy for MMFs' investment decisions. The boxes illustrate left hand side of an MMF's balance sheet.

An illustration of the deposit variable construction is shown in Figure 3. In January of 2021, for example, if an MMF holds repo issued by Bank A in the amount of $100,000 and also commercial paper issued by Bank A in the amount of $400,000, I say that the MMF holds $500,000 worth of deposit issued by Bank A. Following Huber (2023) who uses the same dataset, an MMF's holding of deposit is aggregated to a fund complex or family level. Therefore, throughout the empirical section of the paper, a "fund" refers to a fund complex or a fund family. As dealer banks' balance sheet data on Compustat is published on a quarterly basis, whereas MMFs' portfolio data is published on a monthly basis, I construct the dataset at a monthly frequency and assign the same values to bank balance sheet variables for months that are in the same quarter.[24]

Second, I construct a variable called "Spread" to proxy for safe asset moneyness. The spread variable is going to represent the spread between the yield on the privately produced safe asset that MMFs are holding and the yield on the maturity-matched Treasuries.[25] Treasuries are public safe assets that have the highest moneyness because they are backed by the US government, which means they are perceived to be the safest and the most liquid. This also means the Treasuries earn the most convenience yield or liquidity premium, [26] which makes their yields the lowest.

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[24]Aggregating an MMF's portfolio data to a quarterly frequency is subject to measurement errors as the same asset appears multiple times throughout a quarter if the asset's maturity is longer than a month.

[25]I conduct linear interpolation for in-between maturities.

[26]As shown in prior studies such as Krishnamurthy and Vissing-Jorgensen (2012, 2015).

Figure 4: Spread Variable Plotted Across Time
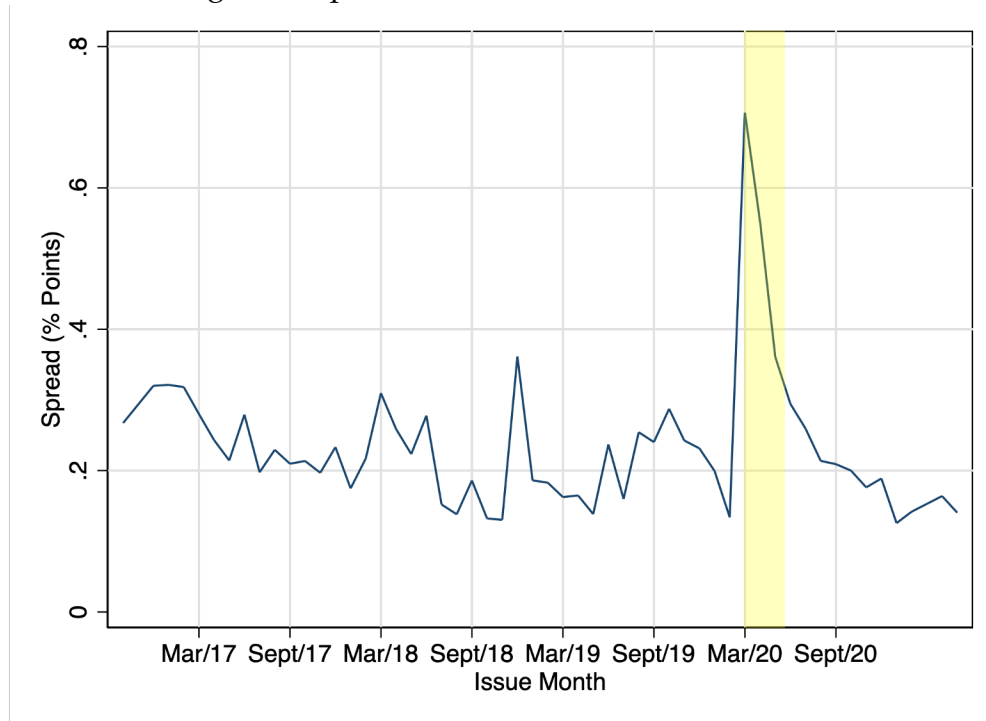
Notes: This figure shows the spread variable plotted month-by-month. The shaded region corresponds to the COVID-19 crisis period from March of 2020 to May of 2020. Spread variable is plotted in terms of percentage points.

If privately produced safe assets are as money-like as Treasuries, the spread will be close to zero. However, if for whatever reason privately produced safe assets become less money-like, banks have to incentivize investors to hold them by offering a higher yield. This means that the convenience yield enjoyed by the dealer banks decreases, widening the spread. Considering this, the Spread variable in month t offered by an MMF f to a dealer bank b can be calculated as follows:

$$Spread_{b,f,t} = \text{Yield on the privately produced safe asset}_{b,f,t} - \text{Yield on the public safe asset}_t$$

Figure 4 shows the Spread variable plotted across time, averaged for each month. We can see that the variable spiked, or in other words the moneyness of the privately produced safe asset decreased dramatically, during the COVID-19 crisis period in March and April of 2020. This is consistent with the established fact in the financial crisis literature that safety and liquidity dry up during crisis periods.[27] Figure 4 validates to a certain de-

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[27]Theoretical evidence is provided in papers like He and Krishnamurthy (2013). Empirical evidence is provided in papers like Gorton and Metrick (2012) and Covitz, Liang, and Suarez (2013).

VARIABLES	Mean	Std. Dev	P25	Median	P75
Deposit ($Billion)	1.08	1.89	0.04	0.26	1.35
Spread (%)	0.18	0.27	0.01	0.13	0.31

gree the use of the constructed Spread variable as a proxy for moneyness of the privately produced safe assets that MMFs hold. Summary statistics for the constructed variable are available in Table 1.

3.3 Empirical Results

3.3.1 Prediction 1: Higher bank ROE results in MMFs' withdrawal

I first test Prediction 1: a dealer bank's ROE affects an MMF's investment decision. I estimate the following model: for each dealer bank b, for each MMF f, for each month t, and for each quarter $q(t)$,[28]

$$\log(Deposit_{b,f,t}) = \alpha + \beta ROE_{b,q(t)-1} + \gamma' X_{b,q(t)-1} + \eta_b + \eta_{f,t} + \epsilon_{b,f,t} \qquad (12)$$

where $Deposit_{b,f,t}$ is the value of assets issued by dealer bank b held by MMF f in month t; $ROE_{b,q(t)-1}$ is the return on equity of the dealer bank b in the previous quarter $q(t)-1$ in terms of percentage points. $X_{b,q(t)-1}$ is a vector of controls that includes the bank size, liability/asset, cash holding, and retained earnings.[29] η_b is the dealer bank fixed effects and $\eta_{f,t}$ is fund-by-time fixed effect.

Notice the timing of the regression: as a dealer bank's balance sheet variable is published at a quarterly frequency and the deposit variable is calculated at a monthly frequency, an MMF observes the announced ROE for the previous quarter and makes the investment decision within the current quarter.[30] Finally, I also estimate the model with an additional lag of the ROE variable ($ROE_{b,q(t)-2}$) to see if the effect of ROE changes is persistent.

The identification assumption made in this analysis is that the error term in Equation

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[28]As mentioned before, dealer bank variables are observed at a quarterly frequency. The function $q(t)$ maps month t to its corresponding quarter. For example, if t is January of 2021, $q(t)$ is the first quarter of 2021, and $q(t) - 1$ is the fourth quarter of 2020.

[29]These control variables are included to take into account higher-ROE banks possibly having better ability to fund their investment activities using their own internal resources instead of relying on external debt financing. It addresses concerns that higher-ROE banks might be demanding less financing through issuing money-like safe assets.

[30]For example, an MMF observes a dealer bank's ROE announced for the fourth quarter of 2020 and use this previous information to makes its investment decision in January, February, and March of 2021.

Table 2: ROE's Effect on Deposit

VARIABLES	(1) log(Deposit)	(2) log(Deposit)	(3) log(Deposit)	(4) log(Deposit)
$\text{ROE}_{q(t)-1}$	-0.0343***	-0.0304***	-0.0287**	-0.0248**
	(0.0121)	(0.0112)	(0.0116)	(0.0108)
$\text{ROE}_{q(t)-2}$		-0.0346***		-0.0346***
		(0.0118)		(0.0122)
Constant	18.81***	18.83***	18.68***	18.70***
	(0.264)	(0.272)	(0.212)	(0.228)
Observations	41,548	41,230	41,540	41,222
R-squared	0.032	0.033	0.278	0.280
Time FE	YES	YES	NO	NO
Bank FE	YES	YES	YES	YES
Fund-Time FE	NO	NO	YES	YES

Notes: The estimated coefficients show the response of the deposit variable in percentage term to a one percent increase in bank ROE. The table also shows the estimated coefficients of the regression with bank and time fixed effects as well as with two-quarter lagged dealer bank ROE. Standard errors are clusterd by fund and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

(12) is not correlated with dealer banks' ROE. This assumption is violated if there are unobserved factors that are correlated with dealer banks' ROE that also affect MMFs' investment decisions. I mitigate this concern by including numerous fixed effects and control variables, and by conducting different robustness checks. By including fund-year-month fixed effects $\eta_{f,t}$, for example, I am comparing assets issued by different dealer banks within the same portfolio of an MMF within the same month, which lets me control for unobserved fund-specific characteristics.
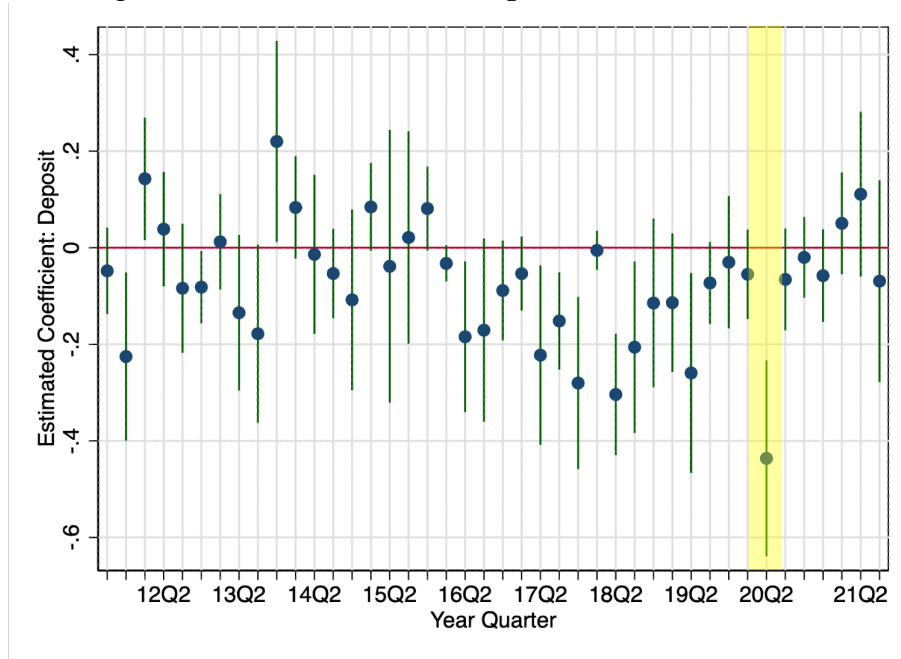
Table 2 shows the estimated coefficients for Equation (12). We can see that a one percentage point increase in ROE of a dealer bank results in a 2.48% decrease in an MMF's holding of privately produced money-like safe assets issued by that dealer bank. Looking at the estimated coefficients on the two-quarter lagged variable, we can see that the effect of changes in ROE is persistent. A one percentage point increase in ROE of a dealer bank two quarters ago results in a 3.46% decrease in an MMF's holding of safe assets issued by that dealer bank.

The economic significance of the result in Table 2 is accentuated when I estimate Equation (12) cross-sectionally quarter by quarter with fund fixed effects.[31] Figure 5 plots the estimated coefficients with 95th confidence intervals.

Consistent with the results shown in Table 2, for most quarters, an increase in ROE

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[31] Adding bank fixed effects will not work as issuer ROE changes at a quarterly frequency.

Figure 5: Estimation of the Deposit Model Over Time

Notes: This figures shows the estimated coefficients for Equation (12) quarter by quarter. The estimation is done without issuer fixed effects as ROE is observed at a quarterly frequency. Dots indicate the estimated coefficients and the lines show the 95% confidence intervals. The shaded regions correspond to the COVID-19 crisis period in the first quarter of 2020. Section 3.4 shows that the result still holds when I take out the COVID-19 crisis period when estimating the model.

of a dealer bank results in MMFs withdrawing from that bank. More interestingly, we can see that the negative response of MMFs' deposit to movements in dealer banks' ROE was especially stronger in the first quarter of 2020, which corresponds to the onset of the COVID-19 crisis when there was severe distress in the financial market. In the first quarter of 2020, a mere one percentage point increase in a dealer bank's ROE resulted in a more than 40% decrease in MMFs' holding of money-like safe assets issued by that bank. In Section 3.4, I show that the main result is not driven only by the COVID-19 period.

The result in this section provides suggestive evidence that MMFs care about the balance sheet condition of the dealer banks. Furthermore, it shows that the ROE of dealer banks is one of the key pieces of variables that MMFs pay attention to when making their investment decisions. What is somewhat surprising and counterintuitive is that MMFs are averse to high profitability of the dealer banks: the more profitable a dealer bank becomes, the more MMFs withdraw from that dealer bank.

3.3.2 Prediction 2: Higher Bank ROE Results in Lower Safe Asset Moneyness

The previous subsection provided suggestive evidence that an increase in a dealer bank's ROE leads to MMFs' withdrawal from that dealer bank. In this subsection, I test Prediction 2 and argue that this empirical pattern is due to the fact that when the ROE of a dealer bank goes up, the safe asset moneyness of that bank decreases.

Whether a financial asset has value not only as a store of value but also as a transactional medium is tested by whether it earns a convenience yield. A convenience yield refers to a nonpecuniary return to assets that asset issuers enjoy for providing a liquidity and/or safety benefit.[32] When a bank can produce safe assets with higher moneyness, investors compensate the bank by offering to lend to the bank at a lower interest rate. Therefore, the Spread variable that I constructed in Section 3.2 is bigger when the bank-issued safe asset has lower moneyness:

$$Spread_{b,f,t} = \text{Yield on the privately produced safe asset}_{b,f,t} - \text{Yield on the public safe asset}_t$$

$$\text{Wider spread} \Leftrightarrow \text{Lower moneyness}$$

I test the hypothesis that an MMF's withdrawal from a dealer bank with a high ROE is due to the safe asset's losing moneyness by estimating the following model: for each dealer bank b, for each MMF f, for each month t, and for each quarter $q(t)$,

$$Spread_{b,f,t} = \alpha + \beta ROE_{b,q(t)-1} + \gamma' X_{b,q(t)-1} + \eta_b + \eta_{f,t} + \epsilon_{b,f,t} \tag{13}$$

where the right hand side of the equation is the same as the first analysis in Equation (12). The Spread and the ROE variables are in terms of percentage points.

Table 3 shows the estimated coefficients. We can see that an increase in a dealer bank's ROE results in a wider spread between the privately produced safe asset yield and the Treasury yield. This means when a bank has a higher ROE, it has to incentivize investors to hold its safe assets by offering a higher interest rate, as the assets are perceived to be less money-like compared to the Treasuries. In other words, the compensation that dealer banks enjoy for issuing safe assets that are money-like decreases when their ROE increases.

I evaluate the economic significance of this result by estimating the coefficients quarter by quarter as I did in Figure 5 of the previous subsection. Figure 6 plots the estimated coefficients and 95th confidence intervals. We can first observe that the effect that a dealer bank's ROE had on the safe asset moneyness is consistently positive across time. More

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[32]Other often-used names of convenience yield include liquidity premium.

Table 3: ROE's Effect on Spread

| VARIABLES	(1) Spread	(2) Spread	(3) Spread	(4) Spread
$ROE_{q(t)-1}$	0.00834***	0.00749***	0.00572**	0.00492**
	(0.00240)	(0.00224)	(0.00260)	(0.00243)
$ROE_{q(t)-2}$		0.00698***		0.00626***
		(0.00190)		(0.00203)
Constant	0.232***	0.222***	0.222***	0.213***
	(0.0445)	(0.0449)	(0.0469)	(0.0471)
Observations	18,528	18,528	18,525	18,525
R-squared	0.188	0.189	0.319	0.320
Time FE	YES	YES	NO	NO
Issuer FE	YES	YES	YES	YES
Fund-Time FE	NO	NO	YES	YES

Notes: The yield data is only available starting October 31 of 2016, henceforth the smaller number of observations compared to Table 2. Variables ROE and spread are in terms of percentage points so that the estimated coefficients show the response of the Spread variable in percentage points to a one percentage point increase in ROE. The table also shows the estimated coefficients of the regression with bank and time fixed effects as well as with two-quarter lagged dealer bank ROE. Standard errors are clusterd by fund and reported in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

interestingly, we can also see that the effect that an increase in ROE had on the safe asset moneyness was especially strong in the second quarter of 2020, which corresponds to the COVID-19 crisis period. In Section 3.4, I show that the main result is not driven only by the COVID-19 period.

Figure 6 provides an explanation for the result shown in Figure 5. In Figure 5, we saw that a negative relationship between a dealer bank's ROE and an MMF's deposit of money in that bank was much stronger during the COVID-19 crisis period. Figure 6 suggests that there was a severe withdrawal from a dealer bank with a high ROE during the COVID-19 crisis period because safe assets issued by a higher-ROE bank had significantly lower moneyness.

The empirical patterns presented in Figure 5 and Figure 6 can be explained using the fact that money-like safe assets are more likely to turn information-sensitive and lose their role as money during a crisis period. Holders of privately produced money-like safe assets are more incentivized to produce private information about the collateral that backs the assets during the crisis period as they are wary of the bank asset being more exposed to the tail risk. But this incentive is especially high for assets issued by banks that are perceived by investors as having a fatter tail in their bank asset value distribution based

Figure 6: Estimation of the Spread Model Over Time
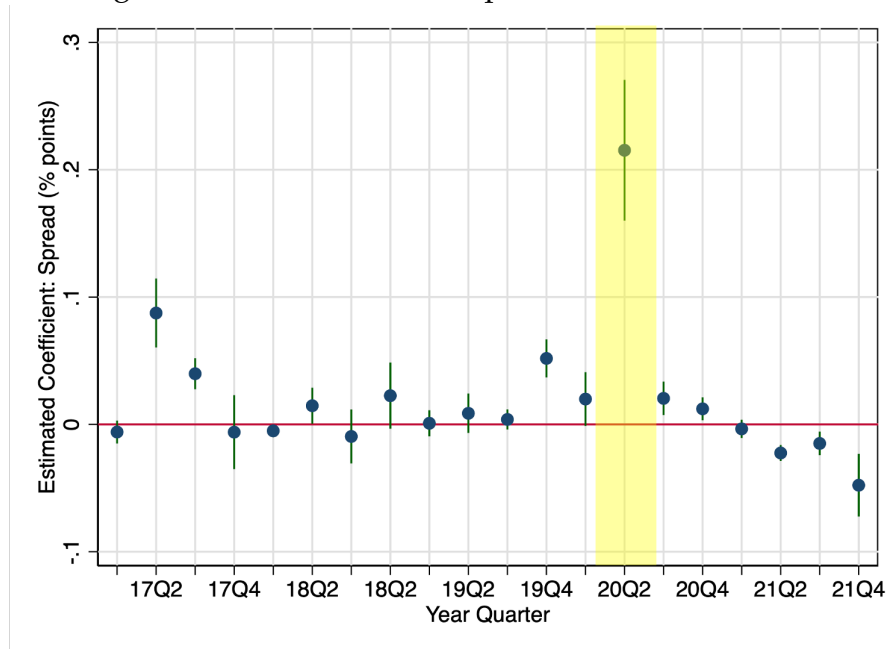
Notes: This figure shows the estimated β for equation (13) quarter by quarter with just fund fixed effects as before. The yield data is only available starting October 31 of 2016. The estimation is done without fixed effects as ROE is observed at a quarterly frequency. Dots indicate the estimated coefficients and the lines show the 95% confidence intervals. The shaded regions correspond to the COVID-19 crisis period in the first quarter of 2020. In Section 3.4, I show that the result still holds when I take out the COVID-19 crisis period when estimating the model.

on the public information that they have–the higher-ROE banks. This logic is consistent with the empirical evidence presented in Meiselman, Nagel, and Purnanandam (2023) where they show that a higher ROE of a bank during a non-crisis period is an indicator of an exposure to systematic tail risk in a subsequent crisis. This mechanism will be formalized as an economic model in the following section.

3.3.3   Prediction 3: MMFs are less responsive to more opaque banks.

In this section, I test Prediction 3. I show that the responsiveness of MMFs' investment decisions and safe asset moneyness to a dealer bank's ROE depends on the dealer bank's degree of opacity. I follow the standard procedure in the literature to construct the measure of bank opacity.[33] Details are in Appendix B.

I test if the results I have shown in the previous sections depend on the bank opacity measure by estimating the following model: for each bank b, each fund f, each month t, and each quarter $q(t)$,

$$y_{b,f,t} = \alpha + \beta_1 ROE_{b,q(t)-1} + \beta_2 Opacity_{b,q(t)} + \beta_3 ROE_{b,q(t)-1} \times Opacity_{b,q(t)} + \eta_b + \eta_{f,t} + \epsilon_{b,f,t}$$
(14)

where the two dependent variables are $\log(Deposit_{b,f,t})$ and $Spread_{b,f,t}$ as in previous analyses. Note that β_1 measures the responsiveness of the dependent variables to the dealer bank ROE when $Opacity = 0$, or in other words the bank is perfectly transparent. β_3 measures how an increase in the bank opacity measure affects the responsiveness of the dependent variables to the delaer bank ROE.

In the model, I showed that if a bank is opaque, the household (the MMFs) has to decipher is a better performance of a bank is due to the bank investing heavily on risky assets or merely due to luck in terms of a higher realization of an exogenous shock. This meant that the moneyness of the deposit is less responsive to a higher ROE of the bank. In the model's context, a higher $Opacity$ variable corresponds to lower $\mathcal{T}$, which made the deposit moneyness θ less responsive to the bank's risky asset holding l. This meant the bank could be more profitable in expectation as they could increase l without instigating a withdrawal from the household.

Table 4 shows the estimated coefficients for Equation (14). We can see in the first row of the table that when a bank is transparent, the responsiveness of both the deposit variable and the spread variable is higher than that when the bank is opaque. In previous sections I showed that a one percentage point increase in a dealer bank's ROE results in about 2-3% decrease in an MMF's holding of safe assets issued by that bank, compared to a 17.7%

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[33]Papers like Beatty and Liao (2014), Jiang, Levine, and Lin (2016), and Chen et al. (2022).

Table 4: Opacity

VARIABLES	(1) log(Deposit)	(2) Spread
$\text{ROE}_{q(t)-1}$	-0.177**	0.0238**
	(0.0682)	(0.0107)
$\text{Opacity}_{q(t)}$	0.185***	-0.0131
	(0.0663)	(0.0130)
$\text{ROE}_{q(t)-1} \times \text{Opacity}_{q(t)}$	0.0346*	-0.00416*
	(0.0182)	(0.00232)
Constant	19.76***	0.130***
	(0.253)	(0.0294)
Observations	10,528	4,589
R-squared	0.048	0.159
Issuer FE	YES	YES
Time FE	YES	YES

Notes: Out of the 13 dealer banks that we used for previous analyses, only three banks (Bank of America, JP Morgan, and Wells Fargo) have the loan loss provisions and non-performing assets data in Compustat. The yield data is only available starting October 31 of 2016, henceforth the smaller number of observations. Spread variable is in terms of percentage points. Robust standard errors are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1

decrease when the bank is transparent as shown in Table 4. In the second row of the table, we can see that an increase in bank opacity results in an inflow of the deposit, suggesting that MMFs prefer banks being opaque to being transparent.[34]

Finally, in the third column, we can see that a one standard deviation decreases the responsiveness of the deposit variable to the dealer bank ROE by about 3.46%. The following column sugggests that this lower responsivenes of the deposit variable to the dealer bank ROE is due to the lower responsiveness of safe asset moneyness when banks are more opaque.

3.3.4 Prediction 4: Opaque banks hold riskier assets

I test Prediction 4, which argues that a dealer bank can afford to hold riskier assets is it is more opaque.

I measure the riskiness of the bank's balance sheet by looking at the Call Reports and

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[34]Why MMFs prefer more opaque banks will be formalized and explain in the model section of the paper.

	(1)	(2)	(3)
VARIABLES	Risk	Risk	Risk
Opacity	0.330***	0.323***	0.156***
	(0.0285)	(0.0286)	(0.0185)
log(Deposit)		0.0134***	0.00429
		(0.00485)	(0.00398)
Spread			-0.0274
			(0.0255)
Constant	63.34***	63.08***	60.92***
	(0.0103)	(0.0952)	(0.0788)
Observations	5,231	5,231	3,217
R-squared	0.987	0.987	0.996
Bank FE	YES	YES	YES
Time FE	YES	YES	YES

Table 5: Opacity

Notes: Out of the 13 dealer banks that we used for previous analyses, only three banks (Bank of America, JP Morgan, and Wells Fargo) have the loan loss provisions and non-performing assets data in Compustat. The yield data is only available starting October 31 of 2016, henceforth the smaller number of observations. Risk-weighted asset data is available from first quarter of 2014. Robust standard errors are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1

taking the ratio of bank b's risk-weighted total asset to its unconditional total asset:

$$Risk_{b,q(t)} = 100 * \frac{\text{Risk-weighted total asset}_{i,q(t)}}{\text{Total asset}_{i,q(t)}}$$

As riskier assets on the bank's balance sheet gets higher risk weights, a higher *Risk* variable corresponds to holding riskier assets. Given this variable, I estimate the following model

$$Risk_{b,q(t)} = \alpha + \beta Opacity_{b,q(t)} + \Gamma X_{b,t} + \eta_b + \eta_t$$

where $X_{b,t}$ is a set of control variables including the Deposit and Spread variable, η_b is back fixed effects and η_t is time fixed effects.

Table 5 shows the estimated coefficient. In the first row, we can immediately see that higher *Opacity* variable is related to higher *Risk*, which means when the bank is more opaque, its balance sheet is riskier. This effect survives even after I include the Deposit and the Spread variables in the regression, which means given that two banks are producing the safe assets that are equal in terms of moneyness, when one bank is more opaque, it can hold more risky assets on its balance sheet.

Tying this result back to the model (Proposition 5), we saw that when the bank is

more opaque, the safe asset holders need to decipher if a higher ROE realization is due to the bank actually holding riskier, higher expected return asset or due to the bank getting lucky and getting hit with a good return shock. This mechanisms makes safe asset holders' investment decision to be less responsive to changes in the riskiness of the bank's balance sheet or changes in realized ROE as we saw in Section 3.3.3, which means the bank can allow itself to hold on to riskier assets without having to worry about its debt losing moneyness.

3.4 Additional Empirical Results and Robustness Checks

Additional empirical results are presented in Appendix A. In Appendix A.1, I show that when controlling for safe asset moneyness, the ROE's effect on MMFs' investment decisions disappears. This means the ROE's effect on safe asset moneyness is the only channel through which it affects MMFs' investment decisions. In Appendix A.3, I show that the effect that I showed until now is nonlinear: that when a bank's ROE is already high, an additional increase in its ROE results in a stronger withdrawal response from MMFs due to a more severe deterioration in moneyness of the safe asset it produces.

I also address possible concerns that one might have about the empirical results. I test the following possibilities: 1) Is it a lower demand for debt financing from the dealer banks? 2) Does the result hold up when controlling for CDS spread? 3) Does the result hold up during normal non-crisis periods? 4) Is movement of only the net income or only the equity driving the result? Details are in Appendix C.

4   Conclusion

In this paper, I showed that profitable banks lose ability to produce money-like safe assets. I first present an economic model. Holders of money-like safe assets regard a higher profitability of the asset issuers as a signal of higher probability that at least a portion of their safe assets cannot be redeemed. This lowers the moneyness of the safe assets.

Then I test model-implied predictions in the data. First, I show that MMFs actually withdraw from more profitable banks in terms of higher ROE. Second, I demonstrate that higher-ROE banks issue safe assets with lower moneyness, which is proxied by the higher yield spread offered to them by MMFs. This second result provides an explanation for why MMFs withdraw from higher-ROE banks that MMFs do not like to hold safe assets with lower moneyness. Third, I find that MMFs' investment decisions are less responsive to changes in a dealer bank's ROE if the bank's opacity measure is high, as moneyness

of safe assets issued by a more opaque bank is less responsive to changes in bank ROE. Finally, I show that a dealer bank can afford to be riskier if it's more opaque.

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Appendix

A Additional Empirical Results

A.1 Bank ROE's Effect Works Through its Effect on Moneyness

We have seen that a movement in dealer banks' ROE affects both MMFs' investment decisions and safe asset moneyness. Now I ask if the ROE's effect on MMFs' investment decisions is only through its effect on safe asset moneyness, or if there is any other channel that ROE affects MMFs' investment decisions.

I test the hypothesis that the deterioration in safe asset moneyness is the only reason why MMFs withdraw from dealer banks with a high ROE by estimating the following model: for each dealer bank b, for each fund f, for each month t, and for each quarter $q(t)$,

$$\log(Deposit_{b,f,t}) = \alpha + \beta_1 ROE_{b,q(t)-1} + \beta_2 Spread_{b,f,t} + \gamma' X_{b,q(t)-1} + \eta_b + \eta_{f,t} + \epsilon_{b,f,t} \quad (15)$$

where I put both the ROE and the Spread variables as independent variables.

Table 6 shows the estimated coefficients for Equation (15). We can see that the estimated coefficients for the ROE variable are statistically insignificant or even positive. On the other hand, the estimated coefficients for the Spread variable are consistently negative. This means the negative effect that a movement in a dealer bank's ROE has on MMFs' investment decisions is soaked up by the movement in the Spread variable. Furthermore, a widening of the spread, which implies lower safe asset moneyness, leads to a withdrawal from such dealer bank, which is also consistent with my hypothesis.

The analysis in this subsection shows that a dealer bank ROE affects MMFs' investment decisions, and its negative effect is only through its effect on the safe asset moneyness. An increased ROE of a dealer bank renders its debt information-sensitive, which leads to its losing its moneyness. This makes MMFs averse to holding such assets, leading to a withdrawal from such dealer bank.

A.2 ROE vs. CDS Spread

I have shown that MMFs withdraw from dealer banks with a higher ROE. The mechanism behind this seeming counterintuitive empirical pattern comes from the fact that safe asset

Table 6: ROE and Spread's Effect on Deposit

VARIABLES	(1) log(Deposit)	(2) log(Deposit)	(3) log(Deposit)	(4) log(Deposit)
$ROE_{q(t)-1}$	0.0216	0.0206	0.0254*	0.0240*
	(0.0132)	(0.0128)	(0.0137)	(0.0125)
$ROE_{q(t)-2}$		0.00903		0.0109
		(0.0126)		(0.0132)
$Spread_t$	-0.394	-0.395	-0.444*	-0.446*
	(0.278)	(0.285)	(0.243)	(0.238)
Constant	18.60***	18.59***	18.15***	18.14***
	(0.543)	(0.580)	(0.551)	(0.525)
Observations	18,528	18,528	18,525	18,525
R-squared	0.045	0.045	0.311	0.311
Time FE	YES	YES	NO	NO
Issuer FE	YES	YES	YES	YES
Fund-Time FE	NO	NO	YES	YES

Notes: Control variables include the dealer banks' asset, liability, and cash/cash-equivalent, and retained earnings. The yield data is only available starting October 31 of 2016, henceforth the smaller number of observations. Spread variable is in terms of percentage points. Standard errors are reported in parenthesis and are clustered by country in which the dealer bank is located. Standard errors are clusterd by fund and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 7: ROE vs. CDS Spread

VARIABLES	(1) All	(2) <90th Percentile ROE	(3) >90th Percentile ROE
$\text{ROE}_{q(t)}$	-0.0348***	-0.0329***	0.235***
	(0.00183)	(0.00175)	(0.00683)
Constant	1.236***	1.204***	-6.242***
	(0.0250)	(0.0264)	(0.802)
Observations	36,184	33,199	2,985
R-squared	0.711	0.776	0.894
Issuer FE	YES	YES	YES
Time FE	YES	YES	YES

Notes: This table shows estimated coefficients of Equation (16). For each column, the regression is run on all of the sample, the sample below the 90th percentile of ROE distribution, and the sample above the 90th percentile of ROE distribution, respectively. Robust standard errors are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1

invesetors associate a higher bank ROE with a higher likelihood of a left tail event as higher-ROE banks are more likely to be engaged in riskier investment activities. This was reflected in lower moneyness of safe assets issued by higher-ROE banks. This mechanism will be formalized in the following section when I present the model.

Given this explanation for the empirical results presented, one can wonder if bank ROE is related to other measures of tail risk. In this section, I relate bank ROE to a more traditional measure of tail risk: the CDS spread. In order to study how bank ROE is related to the bank's CDS spread, I estimate the following model:

$$CDS\ Spread_{b,t} = \alpha + \beta_1 ROE_{b,q(t)-1} + \gamma' X_{b,q(t)-1} + \eta_b + \eta_t + \epsilon_{b,t} \tag{16}$$

Table 7 shows the relationship between ROE and CDS spread. The first column shows the estimated coefficients when the regresssion is run on the entire sample. The second and third columns show the estimated coefficients when the regression is run on the subsample below and above the 90th percentile of ROE distribution, respectively.

When the model presented as Equation (16) is estimated on the entire sample, the result is consistent with our common intuition. A better profitability of a dealer bank in terms of a higher ROE results in a lower probability of default as measured by CDS spread. When the model is estimated on the subsample below the 90th percentile of ROE distribution, the result is the same. However, the sign of the estimated coefficient flips when the model is estimated on the subsample above the 90th percentile of ROE distribution. For high ROE dealer banks, a further increase in their ROE results in a

higher probability of default.

A.3 Bank ROE's Effect is Nonlinear

In this section, I show that the effect of ROE on MMFs' investment decisions and safe asset moneyness is nonlinear. To this end, I reproduce the results shown in Tables 2 and 3 but estimate the models on different subsamples of the ROE distribution.

The estimated coefficients shown in Figure 7 show that MMFs react differently to changes in dealer bank ROE depending on where in the distribution the bank ROE currently is. The top figure plots the estimated coefficients when the dependent variable is $\log(Deposit)$ as in Equation (12) in Section 3.3.1, and the bottom figure plots the estimated coefficients when the dependent variable is $Spread$ as in Equation (13) in Section 3.3.2.

Looking at the top figure, we can first observe that there is a general downward trend on the estimated coefficients as the model is estimated with higher ROE percentile subsamples. When a dealer bank's ROE is high, an additional increase in ROE makes MMFs withdraw more from that bank compared to when a dealer bank's ROE is low. In addition, there seems to be a kink in the MMFs' investment decisions. The effect of changes in ROE on MMFs' investment decisions seems quite muted when the model is estimated on a subsample below the 60th percentile of ROE distribution. The coefficient turns statistically significant at the 5% level when the subsample above the 60th percentile of ROE distribution is included in the estimation.
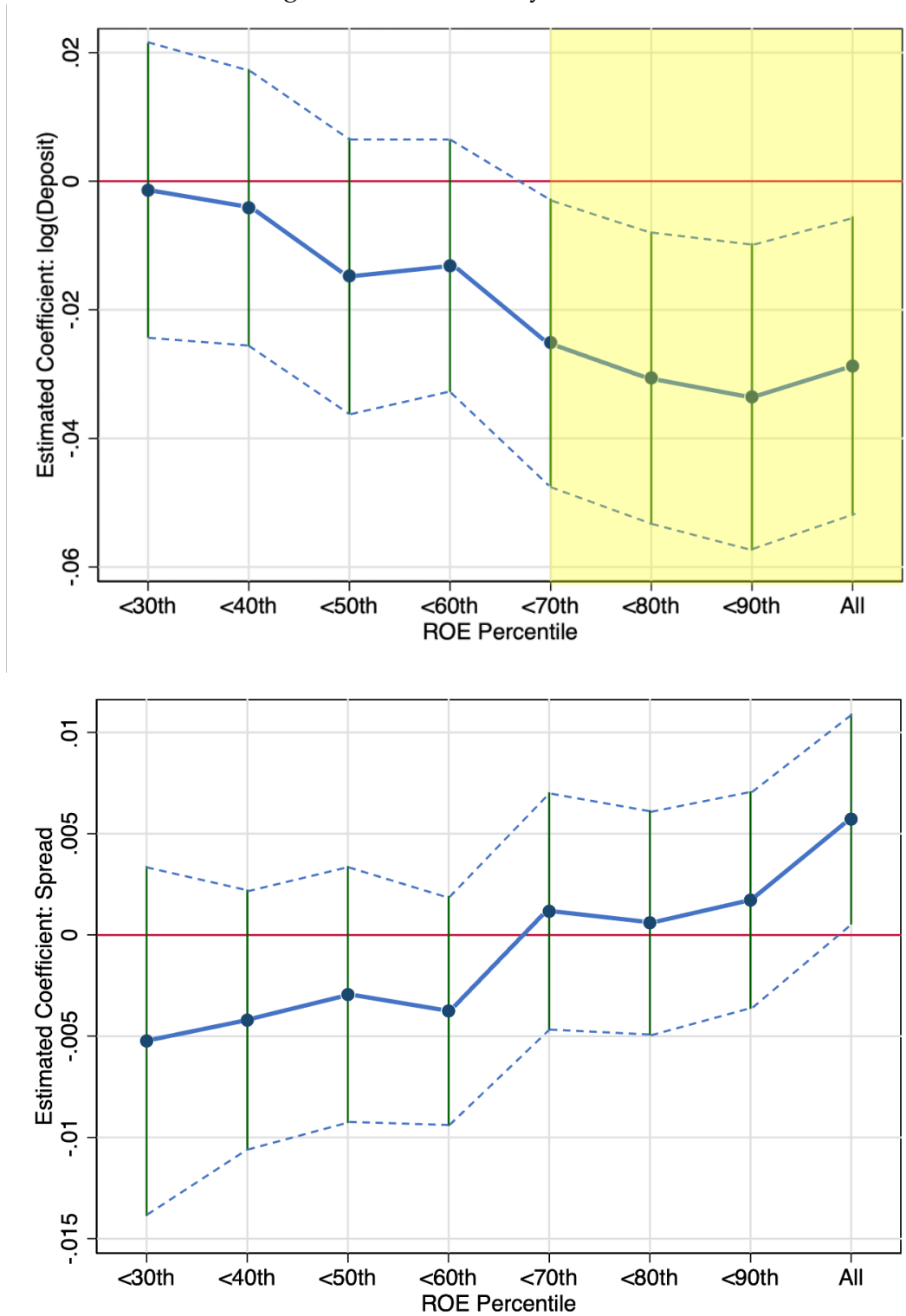
The bottom figure presents the estimated coefficients when the dependent variable is Spread. The result is consistent with what we saw in the top figure as there is a general upward trend on the estimated coefficients. When a dealer bank ROE is already high, a further increase in the ROE results in a significantly lower moneyness of safe assets issued by that bank compared to when the ROE is low.

In Appendix C.2, I provide an explanation for this nonlinearity result by looking at ROE's relationship with a more traditional measure of left tail risk: the CDS spread.[35] When the empirical relationship between ROE and CDS spread is examined on the entire sample, the direction of the relationship is consistent with common intuition: an increase in the bank ROE results in a lower probability of bank default.[36] However, when the empirical relationship between the two variables is investigated only on the subsample of banks with very high ROE, an additional increase in the ROE results in a higher probability of default. Beyond a certain point, a higher profitability signals to investors that the

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[35]The CDS spread data comes from Markit.

[36]This result is consistent with the prior studies such as Chen et al. (2022).

Figure 7: Estimation by Percentile

Notes: This figure shows the estimated coefficients and 95th confidence intervals for Equations (12) (top figure) and (13) (bottom figure) when the model is estimated on different subsamples of the dealer bank ROE distribution. The shade region in the top figure corresponds to where the estimated coefficients are statistically significant.

bank is taking on a lot of risk, raising the prospect of default.

The results shown in this subsection serve as a bridge between the findings I have shown until now and common intuitions and understandings that one has about ROE as a company's performance metric. An announcement of a higher ROE is usually interpreted in the financial market as good news. However, I have shown that a higher ROE can also be interpreted as the bank getting riskier, especially to a subset of investors who hold money-like safe assets issued by dealer banks that are already highly profitable. When the ROE of a bank becomes too high, investors get wary of the fatter tail of the bank asset value distribution.

B   Construction of the Opacity Variable

I follow the literature and look at how changes in various different leads and lags of a bank's non-performing assets (NPA) predict loan loss provisions (LLP).[37] Loan loss provision is an expense that banks set aside when they expect different kinds of losses on their assets due to non-performing assets or counterparty bankruptcy and depends largely on banks' discretions. Approximately following Jiang, Levine, and Lin (2016), I regress loan loss provision on various leads and lags of NPA changes and use the absolute values of the residuals from this model as a measure of disclosure quality or bank opacity.

I first estimate the following model: for each bank b and each quarter $q(t)$

$$LLP_{b,q(t)} = \alpha + \beta_1 \Delta NPA_{b,q(t) \to q(t)+1} + \beta_2 \Delta NPA_{b,q(t)-1 \to q(t)} + \beta_3 \Delta NPA_{b,q(t)-2 \to q(t)-1} + \epsilon_{b,q(t)}$$

where $\Delta NPA_{b,q(t)-1 \to q(t)} = (NPA_{b,q(t)} - NPA_{b,q(t)-1})/Asset_{b,q(t)-1}$. A higher absolute value of the error term means there are higher level of abnormal accruals of loan loss provisions that is not explained by changes in non-performing assets, which are the major driver of loan loss provisions. Banks are being more opaque about possible losses on their assets when this residual is high. I define bank b's opacity level in quarter $q(t)$ as the absolute value of the residuals. I standardized the absolute value for a better interpretation of the scale. Therefore, the variable $Opacity_{b,t}$ is defined as follows:[38]

$$Opacity_{b,t} \equiv \frac{|\epsilon_{b,q(t)}| - \mathbb{E}[|\epsilon_{b,q(t)}|]}{\sigma(|\epsilon_{b,q(t)}|)}$$

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[37]This measure is wide used in the accounting literature in papers such as Beatty and Liao (2014), Jiang, Levine, and Lin (2016), and Chen et al. (2021).

[38]Out of the 14 dealer banks that we used for previous analyses, only three banks (Bank of America, JP Morgan, and Wells Fargo) have the loan loss provisions and non-performing assets data in Compustat.

C   Empirical Robustness Checks

C.1   Is it lower demand for debt financing from the dealer banks?

The central argument of this paper is that safe asset investors like MMFs supply less debt financing to banks with a higher ROE because debt produced by a higher-ROE bank has lower moneyness. However, one could argue that this pattern is there not because MMFs supply less debt financing to high-ROE dealer banks but because high-ROE dealer banks demand less debt financing.

In order to address this concern, I utilize an econometric methodology developed by Amiti and Weinstein (2018), which is a generalization of the method developed in Khwaja and Mian (2008), to separate MMFs' idiosyncratic loan supply shocks from dealer banks' idiosyncratic loan demand shocks. Then I estimate models presented as Equations (12) and (13) with the constructed idiosyncratic dealer bank demand shock variable as an additional control. By doing so, I control for unobserved factors that might hamper a dealer bank's ability to finance themselves by issuing money-like debt such as binding regulatory constraint. This means the response of the deposit variable to changes in dealer banks' ROE is most likely driven by MMFs' supply of deposit.

I utilize econometric methodology developed in Amiti and Weinstein (2018) to address the concern that the empirical pattern shown in this paper is present not because MMFs supply less debt financing to high ROE dealer banks but because high ROE dealer banks demand less debt financing. Amiti and Weinstein (2018) study lending relationships between banks and nonfinancial firms and investigate whether idiosyncratic bank loan supply shocks affect the investment decision of nonfinancial firms. Banks are the agents that supply the loans and nonfinancial firms are the agents that demand the loans. The setting in Amiti and Weinstein (2018) is easily transferable to this paper as this paper is focused on studying the f funding environment where banks are the agents that demand the loans and safe asset investors like MMFs are the agents that supply the loan.

The econometric methodology developed in Amiti and Weinstein (2018) lets me separate MMFs' idiosyncratic loan supply shocks from dealer banks' idiosyncratic loan demand shocks. Their method boils down to estimating the following weighted least squares of the following equation:

$$\underbrace{\frac{Deposit_{b,f,t} - Deposit_{b,f,t-1}}{Deposit_{b,f,t-1}}}_{\text{growth rate of the deposit variable in percentage terms}} = \alpha_{b,t} + \beta_{f,t} + \epsilon_{b,f,t}$$

where $\alpha_{b,t}$ denotes the bank fixed effects and $\beta_{f,t}$ denotes the fund fixed effects with weights being $Deposit_{b,f,t-1}$ (Proposition 2 of Amiti and Weinstein (2018)). There are different nuances to estimating the fixed effects, but the execution of the procedure can easily be done by the accompanying statistical packaged published by the authors that I am immediately put to use.[39]

Table 8: ROE's Effect Controlling for Bank Shock

VARIABLES	(1) log(Deposit)	(2) Spread
$ROE_{q(t)-1}$	-0.0243**	0.00593**
	(0.0109)	(0.00265)
Constant	18.83***	0.238***
	(0.0544)	(0.0432)
Observations	15,306	10,288
R-squared	0.262	0.326

Notes: The estimated coefficients show the response of the deposit variable in percentage term to a one percent increase in bank ROE. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 8 shows the estimated coefficients when the estimated dealer banks' loan demand shock is added as a control variable, which means the response of the Deposit varialble to changes in dealer banks' ROE is most likely driven by MMFs' supply of loans. We can see that even under this setting, the results shown in the main analysis hold up.

C.2   Does the result hold up when controlling for CDS spread?

We saw in Section A.3 that dealer bank ROE and traditional measures of tail risk such as CDS spread are correlated especially when ROE is high. Therefore, it is natural to wonder if the empirical relationships that I presented wash out when I control for CDS spread of each dealer bank. In other words, I test whether ROE is capturing an aspect of tail risk that is different from that captured by the CDS spread.

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[39]The authors made public the AWshock ado file for Stata.

Table 9: ROE's Effect Controlling for CDS Spread

VARIABLES	(1) log(Deposit)	(2) Spread
$\text{ROE}_{q(t)-1}$	-0.0209**	0.000757
	(0.00960)	(0.00363)
$\text{ROE}_{q(t)-2}$	-0.0301***	0.00188
	(0.0103)	(0.00217)
Constant	17.41***	-0.0670
	(0.580)	(0.118)
Observations	36,174	15,825
R-squared	0.289	0.307

Notes: The estimated coefficients show the response of the deposit variable in percentage term to a one percent increase in bank ROE. Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

In order to test whether this is the case, I estimate models presented as Equations (12) and (13) with CDS spread included in the regression. Table 9 shows the estimated coefficients. We can see that even after controlling for dealer banks' CDS spreads, an increase in a dealer bank's ROE is associated with a withdrawal from that bank. The estimates do show that this empirical pattern is due to a decrease in moneyness of safe assets issued by high-ROE dealer banks as measured by an increase in the Spread variable, although the statistical significance is not there.

C.3   Does the result hold up when removing COVID-19 period?

Table 10: ROE's Effect Without the COVID-19 Period

VARIABLES	(1) log(Deposit)	(2) Spread
$\text{ROE}_{q(t)-1}$	-0.0241**	0.00377
	(0.0107)	(0.00228)
$\text{ROE}_{q(t)-2}$	-0.0342***	0.00620***
	(0.0122)	(0.00204)
Constant	18.70***	0.205***
	(0.227)	(0.0473)
Observations	40,898	18,203
R-squared	0.279	0.322

Notes: The estimated coefficients show the response of the deposit variable in percentage term to a one percent increase in bank ROE. Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Figures 5 and 6 suggested that the empirical patterns that were uncovered in this paper were especially salient during the COVID-19 crisis period. We saw that a one percentage point increase in a dealer bank's ROE resulted in more than a 40% decrease in an MMF's holding of safe assets issued by that bank, and this was because of a significant decrease in the assets' moneyness as measured by the Spread variable.

I check whether this pattern holds up during the non-crisis time periods. For this analysis, I estimate the same models presented as Equations (12) and (13) without April of 2020, when the financial turmoil due to the COVID-19 crisis was at its height. Table 10 shows that the result holds up albeit more weakly than in the main analysis.

C.4 Is movements of only the net income or the equity driving the result?

Table 11: ROE's Effect Controlling for CDS Spread

VARIABLES	(1) log(Deposit)	(2) Spread
$\text{Profit}_{q(t)-1}$	0.0135	0.00727
	(0.0268)	(0.00703)
$\text{Equity}_{q(t)-1}$	-0.000651	0.128
	(0.315)	(0.131)
$\text{Profit}_{q(t)-2}$	-0.0524**	0.00383
	(0.0232)	(0.00471)
$\text{Equity}_{q(t)-2}$	1.040**	-0.0135
	(0.443)	(0.110)
Constant	19.24***	0.0999
	(0.840)	(0.0629)
Observations	41,236	18,574
R-squared	0.280	0.326

Notes: The estimated coefficients show the response of the deposit variable in percentage term to a one percent increase in bank ROE. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The central argument of this paper is that a dealer bank's ROE is an important determinant of moneyness of safe assets issued by the bank, and it drives investment decisions of MMFs. However, a bank's ROE is defined as its net profit divided by its equity. Therefore, one can wonder if either a bank's net profit or its equity is solely driving the result. The model mechanism that will be presented in the following section makes it clear that both variables jointly need to drive this result. A higher profit of a bank signals to safe asset

investors that the bank is engaging in riskier investment activities, which increases the tail risk of bank insolvency. A lower equity base decreases the buffer between safe asset investors; i.e. the bank's debt holders, and bank insolvency.

In order to make sure that both the net profit and the equity are jointly driving the result, I estimate models presented as Equations (12) and (13) but with the net income and equity variables as separate independent variables instead of as a ratio.

Table 11 shows that both the profit and the equity are driving the result shown in the main analysis. Given a dealer bank's equity level, an increase in the dealer bank's profit decreases MMFs' holding of safe assets issued by that bank due to a decrease in moneyness of the safe assets (an increase in the Spread variable). Furthermore, given a dealer bank's profit level, an increase in the dealer bank's equity increases MMFs' holding of safe assets issued by that bank due to an increase in moneyness of the safe assets (a decrease in the Spread variable).

D   Proofs

D.1   Proposition 1

Plugging in the budget constraints to the objective function, the problem becomes

$$\max_{m_2} \mathbb{E}_1[(1+r)m_0 - m_1 + \beta(1+r)m_1 + \alpha\theta m_1$$

The first order condition with respect to m_1 is as follows:

$$-1 + \beta(1+r) + \alpha\theta < 0 \text{ if } m_1 = 0$$

$$-1 + \beta(1+r) + \alpha\theta = 0 \text{ if } m_1 > 0$$

Solving for θ, we have the result.

D.2   Lemma 1

We know

$$\mathbb{E}[\theta] = p_H\theta(\tilde{z}_H) + p_M\theta(\tilde{z}_M) + p_L\theta(\tilde{z}_L)$$

where

$$\theta(z) = 1 + \frac{p_{low}[z_{low}l^E(z) + r^s[m_0 + n_0 - l^E(z)] - rm_0 + n_0]}{m_0}$$

for all $z \in \{\tilde{z}_H, \tilde{z}_M, \tilde{z}_L\}$. Take the derivative of θ with respect to l

$$
\begin{aligned}
\frac{\partial \theta}{\partial l}(z) &= \frac{\partial \theta}{\partial l^E} \frac{\partial l^E}{\partial l} \\
&= \frac{p_{low}(z_{low} - r^s)}{m_0} \sum_{j \in \{H,M,L\}} p_j \frac{z - r^s}{\tilde{z}_j - r^s}
\end{aligned}
$$

Due to no short-selling constraint, $\sum_{j \in \{H,M,L\}} p_j \frac{z - r^s}{\tilde{z}_j - r^s} > 0$ for all z, which means $\frac{\partial \theta}{\partial l}(z) < 0$ for all z. Results with bank ROE immediately follow.

D.3 Prosposition 3

I consider three cases: 1) no deposit withdrawal, 2) deposit withdrawal small enough that it requires liquidation of only the safe asset, and 3) deposit withdrawal that requires liquidation of both the safe and risky assets.

Case 1: No deposit withdrawal When there is no deposit withdrawal at date $t = 1$, the marginal benefit of increasing a unit of risky asset holding is $\mathbb{E}_0[1 + z]$, which always outweighs the marginal cost $1 + r^s$. Therefore, l is increased until $\mathbb{E}[\theta] = \theta^*$ as by Lemma 1, $\mathbb{E}[\theta]$ is decreasing in l.

Case 2: Small deposit withdrawal that requires liquidation of only the safe asset When there is a withdrawal at date $t = 1$ but the bank can pay the household off by liquidating only the safe asset, the marginal benefit of increasing the risky asset holding is $\mathbb{E}_0[1 + z]$, which always outweights the marginal cost $1 + r^s$. Therefore, l is increased or equivalently s is decreased until $\mathcal{W} = s$.

Case 3: Big deposit withdrawal that requires liquidation of both the safe and risky asset When there is a big deposit withdrawal at date $t = 1$ that the bank has to liquidate not only the safe asset but also the risky asset, the marginal benefit of increasing a unit of risky asset holding is 0, which is always smaller than the marginal cost, $\delta > 0$. Therefore, l is decreased until either $\mathcal{W} = s$ or $\mathbb{E}[\theta] = \theta^*$ as by Lemma 1, $\mathbb{E}[\theta]$ is decreasing in l.

For case 2, we have

$$
\mathcal{W} = (1 + r)m_0 = s
$$

and substituting $s^* = m_1 + n_1 - l^*$, we have

$$l^* = m_0 + n_0 - (1+r)m_0$$
$$= n_0 - rm_0$$

For cases 1 and 3, we need to calculate l^* such that $\mathbb{E}[\theta] = \theta^*$. For convenience, define $\mathcal{E}(z) = \sum_{j \in \{H,M,L\}} p_j \frac{z - r^s}{\tilde{z}_j - r^s}$.

$$\theta^* = \mathbb{E}[\theta]$$
$$= p_{high}\left[1 + \frac{p_{low}[z_{low}l^E(\tilde{z}_{high}) + r^s(m_0 + n_0 - l^E(\tilde{z}_{high})) - rm_0 + n_0]}{m_0}\right]$$
$$+ p_{med}\left[1 + \frac{p_{low}[z_{low}l^E(\tilde{z}_{med}) + r^s(m_0 + n_0 - l^E(\tilde{z}_{med})) - rm_0 + n_0]}{m_0}\right]$$
$$+ p_{low}\left[1 + \frac{p_{low}[z_{low}l^E(\tilde{z}_{low}) + r^s(m_0 + n_0 - l^E(\tilde{z}_{low})) - rm_0 + n_0]}{m_0}\right]$$
$$= p_{high}\left[1 + \frac{p_{low}[z_{low}l\mathcal{E}(\tilde{z}_{high}) + r^s(m_0 + n_0 - l\mathcal{E}(\tilde{z}_{high})) - rm_0 + n_0]}{m_0}\right]$$
$$+ p_{med}\left[1 + \frac{p_{low}[z_{low}l\mathcal{E}(\tilde{z}_{med}) + r^s(m_0 + n_0 - l\mathcal{E}(\tilde{z}_{med})) - rm_0 + n_0]}{m_0}\right]$$
$$+ p_{low}\left[1 + \frac{p_{low}[z_{low}l\mathcal{E}(\tilde{z}_{low}) + r^s(m_0 + n_0 - l\mathcal{E}(\tilde{z}_{low})) - rm_0 + n_0]}{m_0}\right]$$
$$= p_{high} + \frac{lp_{high}p_{low}\mathcal{E}(\tilde{z}_{high})[z_{low} - r^s]}{m_0} + \frac{p_{high}p_{low}[r^s(m_0 + n_0) - rm_0 + n_0]}{m_0}$$
$$+ p_{med} + \frac{lp_{med}p_{low}\mathcal{E}(\tilde{z}_{med})[z_{low} - r^s]}{m_0} + \frac{p_{med}p_{low}[r^s(m_0 + n_0) - rm_0 + n_0]}{m_0}$$
$$+ p_{low} + \frac{lp_{low}p_{low}\mathcal{E}(\tilde{z}_{low})[z_{low} - r^s]}{m_0} + \frac{p_{low}p_{low}[r^s(m_0 + n_0) - rm_0 + n_0]}{m_0}$$
$$= 1 + \frac{p_{low}[r^s(m_0 + n_0) - rm_0 + n_0]}{m_0} + l\frac{p_{low}(z_{low} - r^s)}{m_0}[p_{high}\mathcal{E}(\tilde{z}_{high}) + p_{med}\mathcal{E}(\tilde{z}_{med}) + p_{low}\mathcal{E}(\tilde{z}_{low})]$$

Solving for l, we have

$$l^* = \frac{\theta^* - 1 - \frac{p_{low}[r^s(m_0+n_0)-rm_0+n_0]}{m_0}}{\frac{p_{low}(z_{low}-r^s)}{m_0}\mathcal{T}}$$
$$= \frac{\theta^* m_0 - m_0 - p_{low}[r^s(m_0 + n_0) - rm_0 + n_0]}{p_{low}(z_{low} - r^s)\mathcal{T}}$$

as desired.

D.4 Proposition 4

We know

$$\frac{\partial \theta_O}{\partial l} = \frac{\partial \theta_O}{\partial l^E} \frac{\partial l^E}{\partial l}$$

and

$$\frac{\partial \theta_O}{\partial l} = \frac{\partial \theta_O}{\partial l^E}$$

Since by definition of $\mathcal{T}$,

$$\frac{\partial l^E}{\partial l} < 1$$

the result automatically follows.

D.5 Proposition 2

When the bank is transparent

$$\theta^* = \theta$$
$$= 1 + \frac{p_L[z_L l + r^s(m_0 + n_0 - l) - rm_0 + n_0]}{m_0}$$
$$\theta^* m_1 = m_0 + p_L[z_L l + r^s(m_0 + n_0 - l) - rm_0 + n_0]$$
$$= m_0 + l p_L(z_L - r^s) + p_{low}[r^s(m_0 + n_0) - rm_0 + n_0]$$

Solving for l, we have

$$l^* = \frac{\theta^* m_0 - m_0 - p_{low}[r^s(m_0 + n_0) - rm_0 + n_0]}{p_{low}(z_{low} - r^s)}$$

D.6 Proposition 5, 6

Immediate from Propostion 4.

E Intuition for l^E

The intuition of the l^E variable is as follows. For illustration, let's suppose that the medium state is realized so that $z = \tilde{z}_M$. As the household does not observe $\tilde{z}_M$, it has to take into consideration the possibility all three cases: z is realized to be $\tilde{z}_H$, $\tilde{z}_M$, and $\tilde{z}_L$.

Case 1: $z = \tilde{z}_M$ **is realized, and the household considers** $z = \tilde{z}_M$ **case.**
The household's estimate of l is such that

$$l^E(\tilde{z}_M|\text{household considers } z = \tilde{z}_H) = \frac{\pi(\tilde{z}_M) - r^s(m_0 + n_0) + r m_0}{\tilde{z}_H - r^s}$$

We can see that if this is the case, an increase in the bank's announced profit $\pi(\tilde{z}_M)$ increases l^E. In fact for this case, as realized z and the household's guess of z coincide, $l^E = l$.[40]

Case 2: $z = \tilde{z}_M$ **is realized, and the household considers** $z = \tilde{z}_H$ **case.**
The household's estimate of l is such that

$$l^E(\tilde{z}_M|\text{household considers } z = \tilde{z}_H) = \frac{\pi(\tilde{z}_M) - r^s(m_0 + n_0) + r m_0}{\tilde{z}_H - r^s}$$

In this case, the effect of an increase in the bank's announced profit $\pi(\tilde{z}_M)$ on l^E is smaller than that in the first case when the household thinks the economy is in the medium state; i.e.

$$\frac{\partial l^E}{\partial \pi(\tilde{z}_M)}(\tilde{z}_M|\text{household thinks } z = \tilde{z}_M) > \frac{\partial l^E}{\partial \pi(\tilde{z}_M)}(\tilde{z}_M|\text{household thinks } z = \tilde{z}_H)$$

as $\tilde{z}_H > \tilde{z}_M$.

The intuition behind this is a follows. The household thinks the same level of the announced profit $\pi(\tilde{z}_M)$ as in the first case is realized with a higher $z = \tilde{z}_H$. This can only happen if the household thinks that the bank got luckier than it actually is and marginal return from the risky asset investment at $t = 0$ is bigger than it actually is. As the household thinks the bank's marginal return on risky asset investment is bigger than it actually is, it think the bank is invested less in the risky asset than it actually is. Therefore for this case, the household's estimate of l is smaller than the actual l; i.e. $l^E < l$. [41]

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[40]This can be shown by simply plugging in (3) into (5).
[41]By simply plugging in (3) into (5), we have

$$l^E(\tilde{z}_H|\text{household thinks } z = \tilde{z}_M) = l * \frac{\tilde{z}_M - r^s}{\tilde{z}_H - r^s} < l$$

as $\frac{\tilde{z}_M - r^s}{\tilde{z}_H - r^s} > 1$ by Assumption **??**.

Case 3: $z = \tilde{z}_H$ is realized, but the household thinks that z is realized to be $\tilde{z}_L$.
The household's estimate of l is such that

$$l^E(\tilde{z}_M|\text{household thinks } z = \tilde{z}_L) = \frac{\pi(\tilde{z}_M) - r^s(m_0 + n_0) + rm_0}{\tilde{z}_L - r^s}$$

In this case, an increase in the profit actually decreases the household's estimate of l as in Assumption **??**, we assumed $\tilde{z}_L < r^s$. In the low state, a marginal increase in the risky asset holding l decreases the bank's profit. If the profit is moderately high with the realized $z = \tilde{z}_M$ but the household thinks that the economy is in the low state, the household infers that the bank is exposed *less* to the risky asset, which bring down its estimate l^E of the bank's risky asset holding. Even in the realized medium state, a marginal increase in l by the bank at $t = 0$ actually decreases l^E if the household thinks the economy is in the low state. Therefore, for this case, $l^E < l$.

The intuition is the same when the state is realized to be $z = \tilde{z}_H$ and $z = \tilde{z}_L$ at date $t = 1$. For each realized state $i \in \{H, M, L\}$, the bank announces profit $\pi(\tilde{z}_i)$, and using that information, the household infers what l is by weighing each case described above with the probability distribution of z. Given $\tilde{z}_i$, the household calculates l^E by

$$l^E(\tilde{z}_i) = p_H l^E(\tilde{z}_i|\text{household thinks } z = \tilde{z}_H) + p_M l^E(\tilde{z}_i|\text{household thinks } z = \tilde{z}_M)$$
$$+ p_L l^E(\tilde{z}_i|\text{household thinks } z = \tilde{z}_L)$$

which is equivalent to Equation (5).

F   Model Extension: Letting r Fluctuate

In this section of the Appendix, I present an extension of the model where I abandon the assumption that r is fixed and let the deposit rate r fluctuate over time. Let r_0 denote the deposit rate going from date $t = 0$ to date $t = 1$ and let r_1 denote the deposit rate going from date $t = 1$ to date $t = 2$. At date $t = 1$, after the bank observes the household's calculation of the deposit moneyness θ, the bank responds by adjusting the deposit rate r_1. Notation-wise, everything else stays the same.

F.1   Household

As before, the household makes its consumption-savings decision after it hears the announcement of the bank's ROE, calculates the deposit moneyness θ, and observes the

deposit rate r_1 set by the bank as a response at date $t = 1$. Given the calculated θ, the household seeks to maximize its expected utility subject to its budget constraint as follows:

$$\max_{c_1,c_2,m_1} \mathbb{E}_1[c_1 + \beta c_2 + \alpha\theta m_1]$$

$$\text{such that } \mathcal{W} \equiv (1 + r_0)m_0 - m_1$$

$$c_1 = \mathcal{W}$$

$$c_2 = (1 + r_1)m_1$$

$$m_0 \text{ given}$$

The first order condition of the household's problem with respect to its date $t = 1$ deposit holding m_1 is as follows

$$-1 + \beta(1 + r_1) + \alpha\theta < 0 \text{ if } m_1 = 0$$
$$-1 + \beta(1 + r_1) + \alpha\theta = 0 \text{ if } m_1 > 0 \tag{17}$$

Given the first order condition above and given the calculated deposit moneyness θ, I can calculate the threshold deposit rate r^* below which the household withdraws everything from the bank and consumes at date $t = 1$:

$$r^* \equiv \frac{1 - \alpha\theta}{\beta} - 1 \tag{18}$$

As before, the deposit serves two role in the model. First, the deposit is a savings vehicle that lets household transfer wealth intertemporally. The value of the deposit as a savings vehicle goes up when the deposit rate r_1 goes up. Second, the deposit is a form of private money. The value of the deposit as private money goes up when the deposit moneyness θ goes up. The first order condition in Equation (17) above suggests when the deposit moneyness θ is high, the household compensates the bank with a lower deposit rate r_1. This compensation from safe asset holders in terms of a lower debt financing rate due to the bank's ability to produce better private money is analogous to convenience yield or the "Spread" variable that proxied for the moneyness of privately produced safe assets held by MMFs that I used in the empirical section of this paper. The expression for the deposit rate threshold in Equation (18) echoes this analysis of the first order condition: when the bank can produce a deposit with a higher moneyness θ, the household agrees to hold the deposit at a lower interest rate.

Figure 8 highlights the insight from the analysis above. The two graphs in the figure

Figure 8: Deposit Supply and Demand
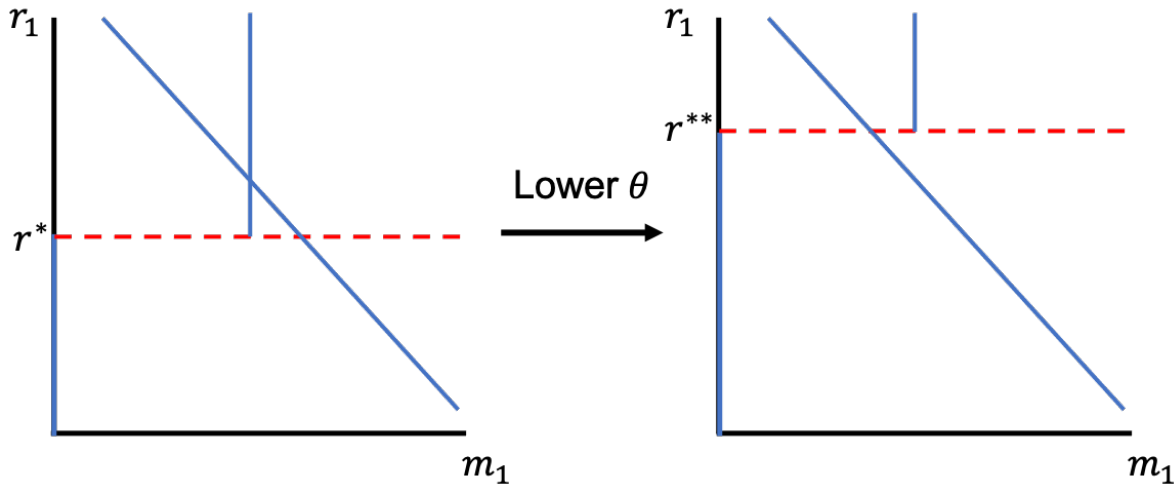
Notes: This figure shows the supply and demand curve in the deposit market. The deposit demand curve stays the same and is downward sloping for illustration purposes. The difference in the deposit supply curve between the left and the right comes from an increase in the threshold deposit rate r^* to r^{**}. This increase in the threshold is due to a decrease in deposit moneyness θ. r^{**} is associated with a deposit with lower moneyness than r^*.

show the supply and demand curves in the deposit market. For illustration purposes, the bank's deposit curve is downward sloping. Looking at the household's deposit supply curve, we can first note that it has a jump at the threshold deposit rate r^* (or r^{**} depending on the figure) calculated in Equation 18.

We start the analysis from the left graph where the threshold deposit rate is r^*, and the household is holding the deposit. As before, since the household is risk neutral, the household's decision is binary. For any offer of deposit rate below r^*, the household withdraws everything from the bank and consumes at date $t = 1$. For any offer of deposit rate above r^*, the household keeps the deposit and consumes in the final date $t = 2$. The left graph shows that the deposit moneyness θ is high enough–or equivalently the threshold deposit rate r^* is low enough–that the household agrees to hold the deposit in equilibrium.

When the deposit moneyness θ goes down, the threshold deposit rate goes up to a new level. The graph on the right shows that when the decrease in θ surpasses a certain level, the threshold deposit rate the household requires to continue to hold the deposit–r^{**} as shown on the right graph–becomes too expensive for the bank. In this case, the household does not supply any deposit, and the market is in disequilibrium.

Proposition 7 summarizes the household's solution to its problem.

Proposition 7. *Solution to the household's problem is as follows:*

66

- If

$$r_1 < r^* \equiv \frac{1 - \alpha\theta}{\beta} - 1$$

the household withdraws everything and consumes at $t = 1$; that is

$$c_1 = (1 + r_0)m_0$$
$$c_2 = 0$$

- If

$$r_1 > r^* \equiv \frac{1 - \alpha\theta}{\beta} - 1$$

the household withdraws nothing and consumes at $t = 2$; that is

$$c_1 = 0$$
$$c_2 = (1 + r_0)(1 + r_1)m_0$$

When the household's preference for money holding α goes up so that the household gets more utility from a marginal increase in money holding, the threshold deposit rate r^* decreases. A higher α means that the value of the deposit as private money became relatively more important to the household than the value of the deposit as a savings vehicle. The household is willing to hold the deposit at a lower interest rate for its benefit as a transactional medium. Furthermore, when the household becomes more patient so that β goes up, the threshold deposit rate r^* decreases. A more patient household is more willing to delay consumption, which means it agrees to hold the deposit at a lower interest rate. This comparative statics is summarized in Corollary

Corollary 2. *The household is willing to hold the deposit at a lower interest rate (i.e. r^* is lower) if*

- *The money demand shifter α increases.*

- *The household time discount factor β increases.*

F.2   Bank

The bank's problem differs from that in the main model because the deposit rate adjusts at date $t = 1$. The asset allocation decision that the bank makes at date $t = 0$ that determines the deposit's moneyness θ which in turn determines the threshold deposit rate r^*

as shown in Equation 18. At date $t = 1$ after the household calculates θ and r^*, the bank can decide whether to set the deposit rate r_1 to be above or below the threshold r^*. If a high deposit rate $r_1 > r^*$ is offered, the household keeps the deposit in the bank. If a low deposit rate $r_1 < r^*$ is offered, the household withdraws from the bank. The deposit rate r_1 the bank sets is only relevant when the household does not withdraw as the household's decision rule is binary. It is obvious that when the household keeps the deposit the interest rate set by the bank is $r_1 = r^*$, which makes the household indifferent between holding the deposit and withdrawing. As before, when there is a withdrawal, the bank's final date net worth n_2 depends on how the magnitude of the withdrawal compares to the bank's safe asset holding.

As the bank is allowed to change the deposit rate at date $t = 1$, the effect of the household's calculation of deposit moneyness θ on the bank's date $t = 2$ net worth n_2 works through θ's effect on the threshold deposit rate r^* as shown in Equation 18. Given this, the bank's problem is again to choose its risky asset holding l and safe asset holding s at $t = 0$ to maximize its expected final date $t = 2$ net worth n_2:

$$\max_{l,s,r_1} \mathbb{E}_0[n_2]$$

$$\text{such that } n_2 = \begin{cases} (1+z)l + (1+r^s)s - r_0 m_0 - (1+r_1)m_1 & \text{if } r_1 \geq \mathbb{E}_0[r^*] \text{ and } \mathcal{W} = 0 \\ (1+z)l + (1+r^s)(s - \mathcal{W}) & \text{if } r_1 < \mathbb{E}_0[r^*] \text{ and } \mathcal{W} < s \\ (1+z)(l - [\mathcal{W} - s]) - \delta(\mathcal{W} - s) & \text{if } r_1 < \mathbb{E}_0[r^*] \text{ and } \mathcal{W} > s \end{cases}$$

$$l + s = n_1 + m_1$$

$$\mathcal{W} = \begin{cases} 0 & \text{if } r_1 \geq r^* \\ (1+r)m_1 & \text{if } r_1 < r^* \end{cases}$$

$$r^* \equiv \frac{1 - \alpha\theta}{\beta} - 1$$

The first case in the bank's net worth calculation refers to when the bank chooses to offer the deposit rate equal to r^* that the household keeps the deposit in the bank. The second and third cases refer to when the bank chooses to let the household withdraw by offering a low deposit rate. The case further divides into if the bank's holding of safe asset is enough to honor the household's withdrawal request. When there is a big deposit withdrawal at date $t = 1$ that the bank has to liquidate not only the safe asset but also the risky asset, which incurs a marginal liquidation cost, $\delta > 0$.

Proposition 8. *Let l^* denote the optimal choice of the bank's risky asset holding l. Then the*

solution to the bank's problem, l^* and $s^* = m_1 + n_1 - l^*$ can be characterized as follows:

- *If the deposit is information-insensitive and there is no withdrawal,*

$$l^* = \frac{\beta m_1(\mathbb{E}_0[z] - r^s) + \alpha m_1 + \alpha p_{low}[r^s(m_1 + n_1) - r_1 m_1 + n_1]}{\alpha p_{low}(z_{low} - r^s)\mathcal{T}}$$

- *If the deposit is information-sensitive and there is a withdrawal, but the withdrawal is small enough that the bank can pay the household off by liquidating only the safe as set, the marginal benefit of increasing l is always bigger than the marginal cost. The solution is at the corner and l is increased or equivalently s is decreased until $\mathcal{W} = s$:*

$$l^* = n_1 - r m_1$$

- *If the deposit is information-sensitive and there is a big withdrawal that the bank has to liquidiate not only the safe asset but also the risky asset the marginal cost of increasing l is always bigger than the marginal benefit. The solution is at the corner and l is decreased until $\mathcal{W} = s$:*

$$l^* = n_1 - r m_1$$

where

$$\mathcal{T} = \mathbb{E}[z - r^s]\mathbb{E}\left[\frac{1}{z - r^s}\right]$$

Proof. As before, we compare case by case. I consider three cases: 1) no deposit withdrawal, 2) deposit withdrawal small enough that it requires liquidation of only the safe asset, and 3) deposit withdrawal that requires liquidation of both the safe and risky assets.

Case 1: No deposit withdrawal: The solution is in the interior as a marginal change in the bank's risky asset holding l affects the bank's debt financing cost for date $t = 1$. The deposit rate r_1 is set so that $r_1 = r^*$ and there is no deposit withdrawal at date $t = 1$. The first order condition of the objective function with respect to the risky asset holding l is

$$\mathbb{E}_0[z] - r^s - \frac{\partial \mathbb{E}_0[r^*]}{\partial l} = 0$$

As

$$\frac{\partial \mathbb{E}_0[r^*]}{\partial l} = \frac{\partial}{\partial l}\left[\frac{1 - \alpha \mathbb{E}_0[\theta]}{\beta}\right]$$

$$= -\frac{\alpha}{\beta}\frac{\partial \mathbb{E}_0[\theta]}{\partial l}$$

$$= -\frac{\alpha}{\beta}\left[1 + \frac{p_{low}[r^s(m_0 + n_0) - r_1 m_0 + n_0]}{m_0}\right.$$

$$\left. + l\frac{p_{low}(z_{low} - r^s)}{m_0}[p_{high}\mathcal{E}(\tilde{z}_{high}) + p_{med}\mathcal{E}(\tilde{z}_{med}) + p_{low}\mathcal{E}(\tilde{z}_{low})]\right]$$

The first order condition becomes

$$\mathbb{E}_0[z] - r^s + \frac{\alpha}{\beta} + \frac{\alpha p_{low}[r^s(m_0 + n_0) - r_1 m_0 + n_0]}{\beta m_0} + l\frac{\alpha p_{low}(z_{low} - r^s)}{\beta m_0}\mathbb{E}[\mathcal{E}] = 0$$

Solving for l,

$$l^* = \frac{\mathbb{E}_0[z] - r^s + \frac{\alpha}{\beta} + \frac{\alpha p_{low}[r^s(m_0 + n_0) - r_1 m_0 + n_0]}{\beta m_1}}{\frac{\alpha p_{low}(z_{low} - r^s)}{\beta m_0}\mathcal{T}}$$

$$= \frac{\beta m_0(\mathbb{E}_0[z] - r^s) + \alpha m_0 + \alpha p_{low}[r^s(m_0 + n_0) - r_1 m_0 + n_0]}{\alpha p_{low}(z_{low} - r^s)\mathcal{T}}$$

Case 2: Small deposit withdrawal that requires liquidation of only the safe asset.
When there is a withdrawal at date $t = 1$ but the bank can pay the household off by liquidating only the safe asset, the marginal benefit of increasing the risky asset holding is $\mathbb{E}_0[1 + z]$, which always outweights the marginal cost $1 + r^s$. Therefore, l is increased or equivalently s is decreased until $\mathcal{W} = s$.

Case 3: Big deposit withdrawal that requires liquidation of both the safe and risky asset. When there is a big deposit withdrawal at date $t = 1$ that the bank has to liquidate not only the safe asset but also the risky asset, the marginal benefit of increasing a unit of risky asset holding is 0, which is always smaller than the marginal cost, $\delta > 0$. Therefore, l is decreased until either $\mathcal{W} = s$. $\square$

G Model Extension: Alternative l^E Inference Process

This section presents an alternative inference process that the household goes through to come up with its guess for the bank's risky asset holding l. This can be thought of as a

stand-in for the main inference process that is presented in Section 2.4.2.

The household only has access to the probability distribution of z and the bank's ROE; i.e. the bank's profit and net worth. Start again from the bank's profit function in Equation (2) and plug in the balance sheet identity $s = n_0 + m_0 - l$:

$$\pi(\underbrace{\overbrace{\tilde{z}_i}^{\text{unobservable}}}_{\text{observable}}) = \underbrace{\tilde{z}_i l}_{\text{unobservable}} + r^s(m_0 + \underbrace{n_0}_{\text{observable}} - \underbrace{l}_{\text{unobservable}}) - rm_0$$

where I indicate what variables are observable to the household and what variables are not. It's important to note that the household *does* observe the bank's profit π, but *does not* observe $\tilde{z}_i$ that makes up the profit π. From the profit equation above , the household can solve for l as follows:

$$l = \frac{\overbrace{\pi(\tilde{z}_i)}^{\text{observable}} - r^s(m_0 + n_0) + rm_0}{\underbrace{\tilde{z}_i}_{\text{unobservable}} - r^s}$$

As $\tilde{z}_i$ is unobservable to the household, l in above is a random variable to the household.

As opposed to the main inference process where the household takes an average of the three l's that emerge depending on the state of the world, the household calculates the estimate l^E by thinking of the worst case scenario. The worst case scenario is when the household is exposed to the low shock the most, which means the bank is invested the most heavily in the risky asset l. This means in order to consider the worst case scenario, we need to take the maximum of the three possible cases as follows:

$$\max \left\{ \frac{\pi(\tilde{z}_i) - r^s(m_0 + n_0) + rm_0}{\tilde{z}_L - r^s}, \frac{\pi(\tilde{z}_i) - r^s(m_0 + n_0) + rm_0}{\tilde{z}_M - r^s}, \frac{\pi(\tilde{z}_i) - r^s(m_0 + n_0) + rm_0}{\tilde{z}_H - r^s} \right\}$$

On top of the household not knowing $\tilde{z}_i$ and l as in the matin model, there is an additional feature of bank opacity for this extension. The household is also aware that due to bank opacity, its estimate is wrong with probability $\mathcal{O}$. $\mathcal{O}$ summarizes the degree of bank opacity, which means the household's guess is more likely to be wrong when the bank is more opaque or when $\mathcal{O}$ is higher.

The household's estimate $l^E(\tilde{z}_i)$ is

$$l^E(\tilde{z}_i) = (1 - \mathcal{O}) \max \left\{ \frac{\pi(\tilde{z}_i) - r^s(m_0 + n_0) + rm_0}{\tilde{z}_L - r^s}, \frac{\pi(\tilde{z}_i) - r^s(m_0 + n_0) + rm_0}{\tilde{z}_M - r^s}, \right.$$
$$\left. \frac{\pi(\tilde{z}_i) - r^s(m_0 + n_0) + rm_0}{\tilde{z}_H - r^s} \right\} + \mathcal{O}\bar{l}$$

so that the household's guess is right with probability $1 - \mathcal{O}$ and wrong with probability $\mathcal{O}$ for some arbitrary parameter value $\bar{l}$. Given this alternative inference process, the solution to the bank's problem is presented as the following proposition.

Proposition 9. *Let l^* denote the optimal choice of the bank's risky asset holding l. Then the solution to the bank' s problem, l^* and $s^* = m_1 + n_1 - l^*$ can be characterized as follows:*

- *If the deposit is information-insensitive and there is no withdrawal,*

$$l^* = \frac{\theta^* m_0 - m_0 - p_L[r^s(m_0 + n_0) - rm_0 + n_0] + \mathcal{O}p_l\bar{l}(1 - z_L)}{p_L(z_L - r^s)(1 - \mathcal{O})[p_H\frac{\tilde{z}_H - r^s}{\tilde{z}_M - r^s} + (1 - p_H)]}$$

- *If the deposit is information-sensitive and there is a withdrawal, but the withdrawal is small enough that the bank can pay the household off by liquidating only the safe as set, the marginal benefit of increasing l is always bigger than the marginal cost. The solution is at the corner and l is increased or equivalently s is decreased until $\mathcal{W} = s$:*

$$l^* = n_1 - rm_1$$

- *If the deposit is information-sensitive and there is a big withdrawal that the bank has to liquidiate not only the safe asset but also the risky asset the marginal cost of increasing l is always bigger than the marginal benefit. The solution is at the corner and l is decreased until $\mathcal{W} = s$:*

$$l^* = n_1 - rm_1$$

Proof. As before, we compare case by case. I consider three cases: 1) no deposit withdrawal, 2) deposit withdrawal small enough that it requires liquidation of only the safe asset, and 3) deposit withdrawal that requires liquidation of both the safe and risky assets.

Case 1: No deposit withdrawal. When there is no deposit withdrawal at date $t = 1$, the marginal benefit of increasing a unit of risky asset holding is $\mathbb{E}_0[1 + z]$, which always outweighs the marginal cost $1 + r^s$. Therefore, l is increased until $\mathbb{E}[\theta] = \theta^*$ as by Lemma 1, $\mathbb{E}[\theta]$ is decreasing in l.

Case 2: Small deposit withdrawal that requires liquidation of only the safe asset.
When there is a withdrawal at date $t = 1$ but the bank can pay the household off by
liquidating only the safe asset, the marginal benefit of increasing the risky asset holding
is $\mathbb{E}_0[1+z]$, which always outweights the marginal cost $1 + r^s$. Therefore, l is increased
or equivalently s is decreased until $\mathcal{W} = s$.

**Case 3: Big deposit withdrawal that requires liquidation of both the safe and risky
asset.** When there is a big deposit withdrawal at date $t = 1$ that the bank has to liquidate
not only the safe asset but also the risky asset, the marginal benefit of increasing a unit of
risky asset holding is 0, which is always smaller than the marginal cost, $\delta > 0$. Therefore,
l is decreased until either $\mathcal{W} = s$ or $\mathbb{E}[\theta] = \theta^*$ as by Lemma 1, $\mathbb{E}[\theta]$ is decreasing in l.

For case 2, we have

$$\mathcal{W} = (1+r)m_0 = s$$

and substituting $s^* = m_1 + n_1 - l^*$, we have

$$l^* = m_0 + n_0 - (1+r)m_0$$
$$= n_0 - rm_0$$

For cases 1 and 3, we need to calculate l^* such that $\mathbb{E}[\theta] = \theta^*$.

$$\theta^* = \mathbb{E}[\theta]$$

$$= p_{high}\left[1 + \frac{p_{low}[z_{low}l^E(\tilde{z}_{high}) + r^s(m_0 + n_0 - l^E(\tilde{z}_{high})) - rm_0 + n_0]}{m_0}\right]$$

$$+ p_{med}\left[1 + \frac{p_{low}[z_{low}l^E(\tilde{z}_{med}) + r^s(m_0 + n_0 - l^E(\tilde{z}_{med})) - rm_0 + n_0]}{m_0}\right]$$

$$+ p_{low}\left[1 + \frac{p_{low}[z_{low}l^E(\tilde{z}_{low}) + r^s(m_0 + n_0 - l^E(\tilde{z}_{low})) - rm_0 + n_0]}{m_0}\right]$$

$$= p_{high}\left[1 + \frac{p_{low}\left[z_{low}\left[(1-\mathcal{O})\frac{\tilde{z}_H - r^s}{\tilde{z}_M - r^s}l + \mathcal{O}\bar{l}\right] + r^s(m_0 + n_0 - \left[(1-\mathcal{O})\frac{\tilde{z}_H - r^s}{\tilde{z}_M - r^s}l + \mathcal{O}\bar{l}\right]) - rm_0 + n_0\right]}{m_0}\right]$$

$$+ p_{med}\left[1 + \frac{p_{low}[z_{low}[(1-\mathcal{O})l + \mathcal{O}\bar{l}] + r^s(m_0 + n_0 - [(1-\mathcal{O})l + \mathcal{O}\bar{l}]) - rm_0 + n_0]}{m_0}\right]$$

$$+ p_{low}\left[1 + \frac{p_{low}[z_{low}[(1-\mathcal{O})l + \mathcal{O}\bar{l}] + r^s(m_0 + n_0 - [(1-\mathcal{O})l + \mathcal{O}\bar{l}]) - rm_0 + n_0]}{m_0}\right]$$

$$= p_H + \frac{lp_Hp_L(1-\mathcal{O})\frac{\tilde{z}_H - r^s}{\tilde{z}_M - r^s}(z_L - r^s)}{m_0} + \frac{p_Hp_L[z_L\mathcal{O}\bar{l} + r^s(m_0 + n_0 - \mathcal{O}\bar{l}) - rm_0 + n_0]}{m_0}$$

$$+ p_M + \frac{lp_Mp_L(1-\mathcal{O})(z_L - r^s)}{m_0} + \frac{p_Mp_L[z_L\mathcal{O}\bar{l} + r^s(m_0 + n_0 - \mathcal{O}\bar{l}) - rm_0 + n_0]}{m_0}$$

$$+ p_L + \frac{lp_Lp_L(1-\mathcal{O})(z_L - r^s)}{m_0} + \frac{p_Lp_L[z_L\mathcal{O}\bar{l} + r^s(m_0 + n_0 - \mathcal{O}\bar{l}) - rm_0 + n_0]}{m_0}$$

$$= 1 + \frac{p_L[z_L\mathcal{O}\bar{l} + r^s(m_0 + n_0 - \mathcal{O}\bar{l}) - rm_0 + n_0]}{m_0} + l\frac{p_L(z_L - r^s)(1-\mathcal{O})}{m_0}[p_H\frac{\tilde{z}_H - r^s}{\tilde{z}_M - r^s} + (1 - p_H)]$$

Solving for l, we have

$$l = \frac{\theta^* - 1 - \frac{p_L[z_L\mathcal{O}\bar{l} + r^s(m_0 + n_0 - \mathcal{O}\bar{l}) - rm_0 + n_0]}{m_0}}{\frac{p_L(z_L - r^s)(1-\mathcal{O})}{m_0}[p_H\frac{\tilde{z}_H - r^s}{\tilde{z}_M - r^s} + (1 - p_H)]}$$

$$= \frac{\theta^*m_0 - m_0 - p_L[z_L\mathcal{O}\bar{l} + r^s(m_0 + n_0 - \mathcal{O}\bar{l}) - rm_0 + n_0]}{p_L(z_L - r^s)(1-\mathcal{O})[p_H\frac{\tilde{z}_H - r^s}{\tilde{z}_M - r^s} + (1 - p_H)]}$$

$$= \frac{\theta^*m_0 - m_0 - p_L[r^s(m_0 + n_0) - rm_0 + n_0] + \mathcal{O}p_l\bar{l}(1 - z_L)}{p_L(z_L - r^s)(1-\mathcal{O})[p_H\frac{\tilde{z}_H - r^s}{\tilde{z}_M - r^s} + (1 - p_H)]}$$

as desired. □

Doing the comparative statics of the optimal l for the case when when the deposit is

information insensitive

$$l^* = \frac{\theta^* m_0 - m_0 - p_L[r^s(m_0 + n_0) - rm_0 + n_0] + \mathcal{O}p_l\bar{l}(1 - z_L)}{p_L(z_L - r^s)(1 - \mathcal{O})[p_H\frac{\tilde{z}_H - r^s}{\tilde{z}_M - r^s} + (1 - p_H)]}$$

with respect to the bank opacity measure $\mathcal{O}$, we can see that

$$\frac{\partial l^*}{\partial \mathcal{O}} = \frac{\overbrace{p_l\bar{l}(1 - z_L)p_L(z_L - r^s)(1 - \mathcal{O})[p_H\frac{\tilde{z}_H - r^s}{\tilde{z}_M - r^s} + (1 - p_H)]}^{(-)} + \overbrace{p_L(z_L - r^s)[p_H\frac{\tilde{z}_H - r^s}{\tilde{z}_M - r^s} + (1 - p_H)]}^{(-)}}{\underbrace{\left(p_L(z_L - r^s)(1 - \mathcal{O})[p_H\frac{\tilde{z}_H - r^s}{\tilde{z}_M - r^s} + (1 - p_H)]\right)^2}_{(+)}}$$

$$> 0$$

which means an increase in the bank's opacity lets the bank invest more in risky asset. This result is consistent with the result presented as Proposition 5 where we saw that an opaque bank can invest more in the risky asset than a transparent bank.